Journal of the
Royal Microscopical Society

CONTAINING ITS TRANSACTIONS AND PROCEEDINGS

AND

A SUMMARY OF CURRENT RESEARCHES RELATING TO

ZOOLOGY AND BOTANY

(principally Invertebrata and Cryptogamia)

MICROSCOPY, &c.

EDITED BY

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Regius Professor of Natural History in the University of Aberdeen

A. N. DISNEY, M.A. B.Sc
F. IAN G. RAWLINS

FELLOWS OF THE SOCIETY,

A. B. RENDLE, M.A. D.Sc. F.R.S. F.L.S.
Keeper, Department of Botany, British Museum

AND

RALPH ST. JOHN BROOKS,
M.A. M.D. D.P.H. D.T.M. & H. (CAMB.)

Minimis partibus, per totum Naturæ campum, certitudo omnis innititur quas qui fugit pariter Naturam fugit.—*Linnæus.*

FOR THE YEAR
1920

TO BE OBTAINED AT THE SOCIETY'S ROOMS
20 HANOVER SQUARE, LONDON, W.1
OF MESSRS. WILLIAMS & NORGATE, 14 HENRIETTA STREET, LONDON, W.C.2
AND OF MESSRS. DULAU & CO., LTD., 34 MARGARET STREET, LONDON, W.1

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Held in January, 1920,

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Any Omissions or Errors in this List should be notified to the Secretary.

LIST OF FELLOWS

OF THE

Royal Microscopical Society

(*Corrected to September 30th*, 1920.)

ORDINARY FELLOWS.

* *Fellows who have compounded for their Annual Subscriptions.*

Elected.

1892 Abraham, Rev. Nendick.
c/o Miss F. Abraham, Sherwood's Buildings, Maritzburg, Natal, S. Africa.

1894 Abrams, Albert, M.D.
2135, *Sacramento-street, San Francisco, Cal., U.S.A.*

1919 Abushady, Ahmed Zahy, L.M.S.S.A.
21, *Cairn-avenue, Ealing, W.*5

1893 Adair, Thomas Stewart, M.D., C.M., Edin.
Storthes-Hall-asylum, Kirkburton, near Huddersfield.

1918 Adams, Basil.
Lynwood, Cromwell-road, Beckenham.

1893 Adams, Charles, M.D.
33, *Bellevue-place, Chicago, Ill., U.S.A.*

1920 Adams, H. V.

1893 Adams, James.
Comely-park, Dunfermline, N.B.

1918 Agate, Charlton S., B.Sc., etc.
Engineering Staff, Marconi Works, Chelmsford.

1892 Aikin, Charles Edmund, M.R.C.S., L.S.A.
Pentre Felin, Llangollen, Denbighshire, North Wales.

1918 Ainslie, Maurice Anderson, Instructor Commander, R.N.
*Royal Naval College, Greenwich, S.E.*10, *and* 8, *Woodville-road, Blackheath, S.E.*3

1906 Aitken, Henry James.
Lauresdale, Wellington-road, Edgbaston, Birmingham.

Elected.
1914 Akehurst, Sydney Charles.
60, *Bowes-road, Palmers Green, N.*13
1913 Allan, Mark J.
"*Ludgershall,*" *Roslyn-street, Middle Brighton, Victoria, Australia.*
1912 Allen, George Morris.
"*Milburn,*" *Bury-street, Euroa, Victoria, Australia.*
1905 *Allis, Edward Phelps, jun., C.E., LL.D., F.L.S., F.Z.S.
Palais Carnolès, Menton, Alpes Maritimes, France.
1919 Alston, Richard A., A.M.C.T.
4, *Colley-street, Old Trafford, Manchester.*
1920 Altof, Mrs. Bertha.
95, *Castlewood-road, Stamford-hill, N.*
1906 Andrews, Cuthbert Otto Ralph.
47, *Red Lion-street, Holborn, W.C.*1
1912 Angus, Herbert Francis.
39, *Empress-avenue, Ilford, Essex.*
1906 Anthony, Charles, F.R.S.E., M.Inst.C.E., M.Am.Soc.C.E., F.R.A.S., F.R.Met.Soc., F.C.S.
Casilla de Correo 149, *Bahia Blanca, Argentine Republic, South America.*
1911 Armstrong, Frank.
78, *Deansgate, Manchester.*
1912 Ash, Lieut. Edward C.
Dallinghoo Hall, Wickham Market, Suffolk.
1909 Ashe, Albert.
55, *Warrior-square, Southend-on-Sea.*
1916 Ashworth, Fred, F.R.Met.Soc., M.S.C.I.
15, *Woodlea, Waterfoot, near Manchester.*
1917 Atkinson, Ernest, A.M.I.L.E., M.I. & S.I.
5, *Bank-road, Workington.*
1915 Attridge, Alfred J.
Ivydene, Rhine-road, Sea Point, Cape Town, S. Africa.
1913 Aubin, Percy Adrian.
10, *Elizabeth-place, St. Helier, Jersey.*
1912 Audas, James W., F.L.S.
"*Engowra,*" 105, *Punt-road, St. Kilda, Melbourne, Victoria.*

1920 Bagnall, Richard Siddoway, F.R.S.E., F.L.S.
Rydal Mount, Blaydon-on-Tyne.
1909 Bagshaw, Walter.
17, *Hereford-road, Harrogate.*
1894 *Bailey, Charles, M.Sc., F.L.S.
Sandhurst, St. Mary Church, Torquay.
1908 Baird, Thomas Stewart, F.I.O., F.S.M.C., D.B.O.A.
54, *St. Enoch-square, and* 34–36, *Queen-street, Glasgow.*
1915 Baker, Arthur.
Davenport Lodge, Pelham-road, Gravesend, Kent.

Elected.
1885 Baker, Frederick Henry, F.L.S.
167, *Hoddle-street, Richmond, Victoria, Australia.*
1894 Baker, Frederick William Watson.
313, *High Holborn, W.C.*1
1914 Baker, Wilfred E. Watson.
313, *High Holborn, W.C.*1
1882 Bale, William Mountier.
83, *Walpole street, Kew, Victoria, Australia.*
1895 Barnard, Joseph Edwin, F.Inst.P.—Hon. Secretary.
Park View, Brondesbury-park, N.W, *and Royal Societies Club, St. James's-street, S.W.*1
1913 Barratt, Thomas Franklin.
Bellmoor, Hampstead Heath, N.W.
1913 Barton, Norman V.
10, *Exhibition-road, S. Kensington, S.W.*7
1874 Bate, George Paddock, M.D., F.R.C.S.E., M.R.C.S., *Surgeon-Lieut.-Col. Army Medical Reserve.*
2, *King Edward-road, Hackney, E.*9
1920 Bates, George Frederick, B.A., B.Sc.
66, *Craigie-road, Perth.*
1918 Baxter, Charles, C.E.
Cleveland-house, Bradford-road, Shipley.
1913 Bayliss, Professor William Maddock, D.Sc., F.R.S.
*St. Cuthbert's, West Heath-road, Hampstead, N.W.*3
1899 Beale, Peyton Todd Bowman, F.R.C.S
" *Oaklands," Hythe, Southampton.*
1915 Beattie, William.
8, *Lower Grosvenor-place, S.W.*1
1885 *Beck, Conrad, C.B.E.
68, *Cornhill, E.C.*3
1899 Beck, Horace Courthope.
*Lister Works, Weedington-road, Kentish Town, N.W.*5
1879 *Bell, Francis Jeffrey, M.A., F.Z.S. *Emeritus Professor of Comparative Anatomy and Zoology in King's College, London, Corresponding Member Linnean Society of New South Wales, Honorary Member Manchester Microscopical Society.*
11, *Aberdeen-chambers*, 43, *Great-Marlborough-street, W.*1
1910 Berridge, Miss Emily Mary, D.Sc., F.L.S.
7, *The Knoll, Beckenham, Kent.*
1918 Berry, John Leslie.
151A, *New-street, Burton-on-Trent.*
1913 Bestow, Charles Horton.
Melford-house, Upper Clapton, N.E.
1919 Bhatia, Bihari Lal, M.Sc., F.Z.S., *Professor of Zoology.*
Department of Zoology, Government College, Lahore, India.
1912 Billinghurst, Humphrey Godwin.
76, *Lebanon-gardens, Wandsworth, S.W.*18
1918 Blackmore, Herbert George.
23, *Gloucester-gardens, W.*2

A 2

Elected.

1899 Bliss, J.
Boar Bank Hall, Grange-over-Sands, Lancashire.

1903 *Blood, Maurice, M.A., F.C.S.
51, *Winchester-avenue, Kilburn, N.W.*6

1916 Bocock, C. Hanslope, F.E.S.
The Elms, Ashley, Newmarket.

1918 Bois, Sir Stanley.
12, *Fenchurch-street, E.C.*

1889 Booth, Miss Mary Ann.
60, *Dartmouth-street, Springfield, Mass., U.S.A.*

1862 Borradaile, Charles.
3, *Norfolk-terrace, Brighton.*

1913 Boyce, David R.
Greenwood-park, Durban, Natal, South Africa.

1914 Boyer, Charles S., A.M.
6140, *Columbia-avenue, Philadelphia, Pa., U.S.A.*

1910 Bracewell, Geoffrey Alfred.
17, *Farcliffe-terrace, Bradford, Yorkshire.*

1918 *Bradshaw, Thomas Buller, J.P.
Millways, Launceston, Cornwall.

1914 Brand, Felix.
37 & 38, *Hatton-garden, E.C.*1

1915 Brewster, Frank.
Criminal Intelligence Office; Simla, India, and The "Dingle," Simla.

1890 Briant, Lawrence, F.C.S., *Mem. Soc. Public Analysts.*
24, *Holborn-viaduct, E.C.*1

1905 Bridge, John William.
Brewer-street, Maidstone.

1908 Brooks, Theodore, B.A. (Cantab.), F.R.G.S., *Member of the Academy of Natural Sciences, Philadelphia, U.S.A., Member of the Entomological Society of America.*
Central Caracas, Caracas Sanba, Clara Provtnce, Cuba.

1887 Browne, Edward Thomas, F.Z.S.
Anglefield, Berkhampstead, Herts.

1911 Browning, Sidney Howard, L.R.C.P., M.R.C.S.
The Station Hospital, Jubbulpore, India.

1920 Brumwell, Harold.
Bengal Tanneries, Ltd., Hide-road, Dock Junction P.O., Calcutta, India.

1919 Brunelle, Major George C., Ph.C., M.D.
200, *Chester Pike, Glen Olden, Pa., U.S.A.*

1920 Bull, Henry H. J.
Albion-cottage, Haddenham, Bucks.

1912 Bullamore, Geo. W.
Walden-cottage, Albury, Herts.

1920 Bullock-Webster, Rev. Canon George R.
17, *Gordon-square, W.C.*

1919 Bumsted, William Frederick.
16, *Conway-avenue, Toronto, Canada.*

Elected.

1920 Burgess, Arthur Savell, M.A., M.B., B.Ch.
c/o Provincial Medical Officer, Kumasi, Gold Coast, West Africa.

1918 Burke, George Edwin.
Box 476, *Colorado Springs, Colorado.*

1913 Burns, Nesbitt, B.A., M.B., B.Ch.
The Lodge, Highbridge, Somerset.

1910 Caird, William John.
Schoolhouse, Sandhaven, Fraserburgh.

1892 Cale, George W., M.D., *Chief Surgeon, St. Louis and San Francisco Railroad Company.*
San Francisco Hospital, 4960, *Laclede-avenue, St. Louis, Mo., U.S.A.*

1920 Cannon, Herbert Graham, B.A., F.Z.S.
Zoology Department, Imperial College of Science and Technology, and 62, *Stockwell-park-road, Stockwell, S.W.*9

1913 Capell, Bruce J.
10, *Castelnau, Barnes, S.W.*13

1891 Carlier, Edmond William Wace, M.D., B.Sc., *Professor of Physiology, Mason University College, Birmingham.*
Morningside, Granville-road, Dorridge, near Birmingham.

1880 *Carruthers, William, Ph.D. F.R.S., F.L.S., F.G.S.
44, *Central-hill, Norwood, S.E.*19

1910 Carter, John Arthur, Assoc.M.I.M.E.
6, *Temple-road, Stowmarket, Suffolk.*

1861 *Cattley, Edward Abbs.
Officer Str[t]. 5, *lodg.* 15, *St. Petersburg, Russia.*

1918 Cattley, Major Robert, M B., C.M., B.Sc., etc.
43, *Main-avenue, Heworth, York.*

1903 Chapman, Alfred Chaston, F.R.S., F.I.C., F.C.S.
8, *Duke-street, Aldgate, E.C.*3

1892 Chapman, Frederick, A.L.S., *Palæontologist to the National Museum, Melbourne; Hon. Palæontologist, Geological Survey, Victoria; President. Microscopical Society, Victoria; Lecturer and Demonstrator in Palæontology, Melbourne University.*
'Croham Hurst," Threadneedle-street, Balwyn, near Melbourne, Victoria, Australia.

1911 Chatwin, Charles Panzetta.
32, *Cassland-road, Thornton-heath, Surrey.*

1909 Cheavin, Captain W. H. S., F.C.S., F.E.S.
*Middlesex Medical College, Berners-street, W.*1

1904 Cheshire, Professor Frederic John, C.B.E., F.Inst.P., *Director of Technical Optics, Imperial College of Science and Technology, South Kensington, S W.*7
23, *Carson-road, West Dulwich, S.E.*

Elected.

1885 Clark, Joseph.
Hind Hayes, Street, S.O., Somerset.

1917 Clemence, Walter, M.I.Mech.E.
1, *Park-terrace, Nottingham.*

1914 Clibborn, Lt.-Col. John, C.I.E., B.A.
87, *Victoria-street, S.W.*1

1907 Clowes, William Archibald, F.Z.S.
*Duke-street, Stamford-street, S.E.*1

1919 Coghill, Douglas.
The Dominion Laboratory, Sydney-street, Wellington, New Zealand.

1905 Cole, Thomas Skelton.
Westbury, 7, *Endcliffe-crescent, Sheffield.*

1908 Connell, John Gibson.
Biology Department, Glasgow Provincial Training College, Cowcaddens-street, Glasgow, and 22, *Bellwood-street, Glasgow.*

1919 Constantine, Rev. Allan W., B.A.
Grafton Lodge, Muizenburg, Cape Peninsula, South Africa.

1920 Cooke, William Edmund, M.D., F.R.C.P., D.P.H.
Public Health Department, Town Hall, Bermondsey, S.E.

1875 Cowan, Thomas William, F.L.S., F.G.S.
Sutherland-house, Clevedon, Somerset.

1881 Creese, Edward James Edgell, F.Z.S.
3, *Goswell-villas, London-road, Newbury, Berks.*

1884 *Crisp, Lady Catherine.
5, *Lansdowne-road, Notting-hill, W.*

1891 Crowther, Henry.
Curator, The Museum, Leeds.

1919 Curties, Charles Lees.
244, *High Holborn, W.C.*1

1913 Cuzner, Edgar.
36, *Trothy-road, Bermondsey, S.E.*1

1920 Da Fano, Corrado, M.D., L.D.
*King's College, Strand, W.C.*2

1914 Daniels, Major William Cooke.

1916 Davies, Alfred T.
Avon-house, Keynsham, near Bristol.

1908 Davies, Daniel.
c/o Messrs. McGruer, Davies & Co., Timaru, New Zealand.

1915 Denne, Mark Thomas, O.B.E.
74, *Hornsey-lane, Highgate, N.*6

1885 De Witt, William G.
88, *Nassau-street, New York, U.S.A.*

1904 Dibdin, William Joseph, F.I.C., F.C.S.
31, *Idmiston-road, West Norwood, S.E.*27

Elected.
1918 Digby, Miss Lettice.
Kings Ford, Colchester.
1913 Dinsley, Lieut. Alfred, R.A.O.C.
c/o Sir C. R. McGrigor, Bart., & Co., 29, *Panton-street, Haymarket, S.W.*
1886 Disney, Alfred Norman, M.A., B.Sc.
14. *Wilton-crescent, Wimbledon, S.W.*19
1918 *Dixon, Miss Annie.
43, *Pine-road, Didsbury, Manchester.*
1896 Dixon, Walter.
38, *Bath-street, Glasgow.*
1892 Dixon-Nuttall, Frederick Richard.
Ingleholme, Eccleston-park, near Prescot, Lancashire.
1919 Dovey, Ernest Roadley, A.R.C.S.
Government Laboratory, Hongkong, China.
1907 Dowdy, Sidney Ernest, M.P.S.
1, *Belton-villas, Hill-road, Dovercourt, Essex.*
1918 Downes, Harold, M.B., C.M., L.R.C.P., etc.
Ditton Lea, Ilminster, Somerset.
1919 Drescher, Theodore Bausch.
149, *Westminster-road, Rochester, N.Y., U.S.A.*
1919 Drew, Aubrey H., D.Sc.
Imperial Cancer Research Fund, 8–11, *Queen-square, W.C.*1
1910 Dumat, Frank Campbell.
26, *Standard Bank-chambers, Johannesburg, Transvaal, South Africa.*
1894 Duncan, Cecil Cooke, F.I.C., F.C.S.
The County Chemical Laboratory, Shire Hall, Worcester.
1911 Duncan, Francis Martin, F.R.P.S., F.Z.S.
37A, *Belsize-square, N.W.*3
1919 *Dunn, Gano, A.I.E.E.
J. G. White Engineering Corporation, 43, *Exchange-place, New York, U.S.A., and* 117, *West* 58*th Street, New York.*
1919 Dunn, Reginald.
90, *Lorne-road, Clarendon-park, Leicester.*
1920 Durand, Alexandre.
16, *Rue Casimir Delavigne, Havre, France.*

1910 Earland, Arthur.
Aviemore, 34, *Granville-road, Watford, Herts.*
1907 Eastham, John W., B.Sc. (Edin.).
Vernon British Columbia.
1912 Edwardes, Seabury.
Burma Excise Department, Moulmein, Lower Burma.
1899 Elliott, Oliver Thomas, M.P.S., Ph.C.
c/o Messrs. Philip Harris & Co., Edmund-street, Birmingham, and The Rowans, Lloyd's-street, Small Heath.

Elected.

1919 Elliott, Thomas Gifford, F.I.C., F.C.S.
Research Laboratory, Hecla Works, Sheffield, and Hillcote, Park Edge, Hathersage, near Sheffield.

1907 Ewell, Marshall D., M.D.
749, *Tate-avenue, Memphis, Tenn., U.S.A.*

1897 Eyre, John William Henry, M.D., M.S.Durh., D.P.H., F.R.S.E. —PRESIDENT, *Professor of Bacteriology in the London University.*
*Bacteriological Laboratories, Guy's Hospital, S.E.*1, 62, *Wimpole-street, W.*1, *and The Warren, Tulse-hill, S.W.*2

1883 *Fawcett, John Edward.
Heron-court, Farnham, Knaresborough.

1883 Fellows, Charles Sumner.
107, *Chamber of Commerce, Minneapolis, Minnesota, U.S.A.*

1917 Fendick, Ernest A.
Wicklewood, 22, *Finedon-road, Wellingborough.*

1909 Ferguson, Arthur Duncan.
British Guiana Bank, Georgetown, Demerary, British Guiana.

1904 Fischer, Charles Edward Max, M.D., *Associate Professor of Biology, Histology, and Embryology, College of Physicians and Surgeons of the University of Illinois, Memb. Amer. Microscopical Soc., Memb. of the Amer. Assoc. for the Advancement of Science.*
Suite 1320–2, 25, *E. Washington-street, Chicago, Ill., U.S.A.*

1866 *Fitch, Frederick George.
34, *Hamilton-terrace, N.W.*8

1902 Flatters, Abraham.
Syddal-cottage, Bramhall, Cheshire.

1919 Fleuret, John B.
47, *Walsingham-road, Hove.*

1917 Fotheringham, William, J.P.
Hillhead, Lerwick, Shetland.

1915 Francis, Miss Lilian Angela.
9, *Henrietta-street, Cavendish-square, W.*1

1912 Gadd, Arthur.
115, *Atwood-road, Didsbury, near Manchester*

1918 Garbutt, Ernest Chalders.
York-house, St. Ives, Cornwall.

1902 Gardner, William.
292, *Holloway-road, N.*7

Elected.

1911 Garforth, Sir William Edward, LL.D.
Snydale Hall, Normanton.

1919 Garnett, John Benbow.
309, *Oxford-road, Manchester.*

1920 Gatenby, James Bronté, B.A., B.Sc., D.Phil.(Oxon), *Lecturer in Cytology.*
*University College, Gower Street, W.C.*1

1920 Gauntlett, H. Leon, M.R.C.S., L.R.C.P.
45, *Hotham-road, Putney, S.W.*15

1905 Gettys, Henry B., M.D.
3526, *Washington-avenue, St. Louis, Mo., U.S.A.*

1910 Gibbs, Miss Lilian S., F.L.S.
22, *South-street, Thurloe-square, S.W.*

1902 Gibson, Joseph.
Elmfield, Psalter-lane, Sheffield.

1919 Gibson, William H., M.B.E., D.Sc.
York-street Flax Spinning Co., Ltd., York-street, Belfast.

1892 Gifford, James William.
Oaklands, Chard, Somerset.

1899 Gleadow, Frank.
Bakeham-house, Englefield Green, Surrey.

1912 Glover, Samuel.
Olive Mount, St. Ann's, St. Helens, Lancashire.

1910 Gooding, Henry Cornish.
Ipswich-street, Stowmarket, Suffolk.

1908 Gordon, David.
Care of D. & W. Murray, Ltd., Adelaide, South Australia.

1909 Gordon, Fred. William.
61, *Broadway, New York City, U.S.A.*

1885 Gordon, Rev. J. M., M.A.
7, *Moreton-gardens, S.W.*5

1920 Graham, Joseph, B.Sc.
Glen Hurst, Corbridge-on-Tyne.

1919 Grant, Ernest Henry.
Britannia-villas, Chesham, Bucks.

1904 Griffiths, Waldron.
1, *Cecily-hill, Cirencester.*

1910 Grundy, James.
96, *Teignmouth-road, Cricklewood, N.W.*2

1912 Gurrin, Gerald Francis.
59, *Holborn-viaduct, E.C.*1

1902 Güssow, Hans Theodore.
Chief, Division of Botany, Dominion Experimental Farm, Ottawa, Canada, and 43, *Fairmount-avenue, Ottawa, Canada*

1910 Gwynne-Vaughan, Dame Helen Charlotte Isabella, D.Sc., F.L.S., *Head of the Department of Botany, Birkbeck College, E.C.*4
93, *Bedford-court-mansions, W.C.*1

Elected.

1919 Hadfield, Sir Robert A., Bart., D.Sc., F.R.S., F.Inst.P.
22, Carlton-house-terrace, S.W.1

1893 Hägler, Elmer Ellsworth, M.D.
The Hägler Building, 401, *East Capitol-avenue, Springfield, Illinois, U.S.A.*

1914 Halford-Roberts, Stanley.
Edenholme, East Boldon, near Newcastle-on-Tyne.

1912 Hall, Rev. C. A.
"Woodburn," Clynder, Dumbartonshire.

1920 Hall, T. D. Tuton.
Technical School, Rochdale.

1885 Hallam, Samuel Robinson, L.S.A. (Lond.), L.M.S.S.A.
586, *Old-Kent-road, S.E.1*

1920 Hallowes, Kennett Knight, M.A., F.G.S., A.R.S.M., A.Inst.M.M., *Assistant Superintendent, H.M. Geological Survey of India.*
27, *Chowringhill, Calcutta, India, and* 50, *Regent's-park-road, N.W.*

1919 Hampshire, Percy.
5, *Kensington-terrace, Leeds.*

1882 *Hanaman, Charles Edward.
103, *First-street, Troy, N.Y., U.S.A.*

1874 †Hanks, Professor Henry.
1124, *Greenwich-street, San Francisco, California, U.S.A.*

1914 Harding, H. Bertram, F.L.S.
77, *Hannah-street, Porth, Glam.*

1905 Hardy, Alfred Douglas, F.L.S.
State Forests Department, Melbourne, Yarra-langi, Studley-avenue, Kew, Melbourne, Victoria, Australia.

1905 Harris, Charles Poulett, M.D. (Lond.), M.R.C.S., L.R.C.P.
192, *Lower Addiscombe-road, Croydon, S.E.*

1919 Harper, Captain Raymond Sydney, M.R.C.S., L.R.C.P., R.A.M.C.
4, *Adelaide-crescent, Hove.*

1912 Harrison, James.

1915 Hartland, Albert J.
22, *Cambridge-road, King Williams Town, Cape Province, S.A.*

1867 *Hartree, William, Associate Inst. C.E., F.Z.S.
Havering, Tunbridge Wells.

1911 Hartridge, Hamilton, M.A., M.D.
King's College, Cambridge.

1919 Harvey, John Henry, F.C.S.
Ravensworth, Llantarnam, Newport, Mon.

1897 Hassall, John, M.D., M.R.C.S., &c.
Ingleside, Mouldsworth, near Chester.

1910 Hately, John Craig.
70, *Board of Trade, Chicago, Ill., and Galewood, Lake Geneva, Wiss., U.S.A.*

† Corresponding Fellow.

Elected.

1919 Hawksley, Charles Worthington.
83, Wigmore-street, W.1, and 13 Alma-square, St. John's-wood, N.W.8

1916 Hazeldine, Frederick James.
Barnfield, South Godstone, Surrey.

1909 Heath, Charles Emanuel.
178, *Loughborough-road, Brixton, S.W.9*

1909 Heath, Ernest.
Clidga, Sennen, Cornwall.

1899 Heaton, John, F.C.S.
Southcliffe, Roker, Sunderland.

1917 Hensman, Leonard Newton, Ph.C., M.P.S.
2, *Killarney-road, Wandsworth, S.W.18*

1889 Hepworth-Collins, Walter, F.G.S., F.C.S.
Junior Constitutional Club, Piccadilly, W.

1891 Heron-Allen, Edward, F.R.S., F.L.S., F.G.S., F.Z.S., M.R.I.A., etc.
33, *Hamilton-terrace, N.W.8, and "Large Acres," Selsey-bill, Sussex.*

1910 Hewlett, Richard Tanner, M.D., F.R.C.P., D.P.H.
Professor of Bacteriology, Bacteriological Laboratory, King's-college, Strand, W.C., and 12 *Colinette-road, Putney, S.W.15*

1904 Hill, Cyril Francis, M.Inst.M.M.
Druids-croft, Kinnaird-avenue, Bromley, Kent.

1881 *Hill, Joseph Alfred, F.L.S.
St. Bees, Northumberland-road, Leamington.

1906 Hiscott, Thomas Henry.
16, *Woodville-road, Ealing, W.5, and* 5, *Stone-buildings, Lincoln's Inn, W.C.*

1917 Hitchins, Alfred Bishop, Ph.D., D.Sc., A.M.
c/o Ansco Co., Research Laboratory, Binghampton, N.Y., U.S.A.

1920 Hornyold, Professor Alfonso G., D.Sc.
Professor Agregardo of the Marine Biological Laboratory, Porto-Pi, Palma de Mallorca, Spain.

1918 Hort, Edward C., F.R.C.P.
8, *Harley-street, W.1*

1918 Hoseason, William Sandford.
Dockmaster's Office, Alexandra Dock, Bombay, India.

1891 Howard, A. Dashwood, B.A., M.D., M.R.C.S., L.R.C.P.
"The Corner," Hampton-hill, Middlesex.

1917 Howard, Henry J.
94, *Rosary-road, Thorpe, Norwich.*

1894 Howard, Capt. Robert Nesbit, M.R.C.S., S.A.M.C.
No. 2 General Hospital, Maitland, near Cape Town, S.A.

1889 Huber, Gotthelf Carl, M.D., *Professor of Histology and Embryology, and Director of the Histological Laboratory in the University of Michigan.*
1330, *Hill-street, Ann Arbor, Mich., U.S.A.*

Elected.
1918 Hughes, Owen Lloyd.
Ael-y-Bryn, Henllan, Trefnant, Denbighshire, N. Wales.
1913 Hughes, R. H. Pullen.
Alexander-house, 141, *Duke-street, Southport.*
1911 Huish, Charles Henry.
"*The Limes,*" 63, *London-road, Redhill, Surrey.*
1913 Hurrell, Harry Edward.
25, *Regent-street, Great Yarmouth.*

1867 Ingpen, John Edmund.
21, *Wrotham-road, Broadstairs.*
1920 Ireland, William Jabez.
6, *Hurlingham-road, Fulham, S.W.*6
1903 Ives, Frederic Eugene, F.R.P.S., *Member of the Franklin Inst., N.Y., Camera Club, and American Microscopical Soc.,* F.A.A.A.S.
1327, *Spruce-street, Philadelphia, Pa., U.S.A.*
1909 James, Robert Denley.
1901 Johnson, Charles Harold, M.D., C.M., F.R.C.S.E.
Weyanoke, Kerang, Victoria, Australia.
1912 Johnston, Thomas Harvey, M.A., D.Sc., F.Z.S.
Biology Department, The University of Queensland, Brisbane, Australia.
1918 Jones, Sir Bertram Hyde, K.B.E.
Ilgars, Runwell, Wickford, Essex.
1910 Jones, William Llewellyn.

1885 Karop, George C., M.R.C.S.
Inniscorrig, Beltinge-road, Herne Bay.
1910 Keeley, Frank J., B.S., E.M., *Member of the Council, Academy of Natural Sciences, Philadelphia; Vice-Director, Mineralogical Section, Academy of Natural Sciences, Philadelphia.*
Box 25, *Merion Station, Penna, U.S.A.*
1919 Keen, Percy Frederick.
64, *Fairholt-road, Stamford-hill, N.*16
1918 Kidd, Robert Hicks.
Marlborough-house, Newbury, Berks.
1912 King, Mrs. Cecil.
33, *Evelyn-gardens, South Kensington, S.W.*7
1909 Kirby, Edwin Henry.
The Sungei Bahru Rubber Estates, Ltd., Home Division, Alor Gaja, Malacca.
1898 Kirkman, Hon. Thomas.
Croftlands, Esperanza, Natal, S. Africa.
1905 Kitchin, Joseph.
The Mount, 53, *Park-hill-road, Croydon.*

Elected.

1897 Klein, Sydney Turner, F.L.S., F.R.A.S., F.E.S.
Lancaster-lodge. Kew-gardens, Surrey.

1913 Koch, Victor M. E.
c/o Messrs. Martin and Tomkins, 51, *Margaret-street*, *W*.1

1920 Lamb, Morris Charles, F.I.C.
176, *Tower-Bridge-road*, *S.E.*1

1915 Lambert, Joseph.
68, *Dartmouth-road*, *Cricklewood*, *N.W.*2

1918 Lancaster, Henry C.
39, *Ladbroke-grove*, *Holland-park*, *W.*

1920 Langeron, Maurice C. P., *Docteur en Médicine*, *Chef de Laboratoire á la Faculté de Médicine de Paris.*
15, *Rue de l'Ecole de Médicine*, *Paris*, *France.*

1865 Lankester, Sir Edwin Ray, K.C.B., M.A., LL.D., F.R.S., F.L.S., F.Z.S., *Hon. Fellow of Exeter College, Oxford.*
29, *Thurloe-place*, *S.W.*7

1887 Latham, Miss Vida Annette, M.D., D.D.S.
1644, *Morse-avenue*, *Roger's-park*, *Chicago*, *Ill.*, *U.S.A.*

1919 Lauwers, Walter H. M., F.P.S.L.
77, *Rue Lamoriniere*, *Antwerp*, *Belgium.*

1919 Lawrie, Leslie G.
Stornoway, *Holden-road*, *Kersal*, *Manchester.*

1912 Lawson, Peter.
"*Jesmond*," *Nella-road*, *Fulham-palace-road*, *Hammersmith*, *W.*6

1914 Leeson, John Rudd, J.P., M.D., F.L.S., F.R.A.S.
Clifden House, *Twickenham.*

1919 Lissimore, Norman.
Ryde Villa, *Dixon's-green*, *Dudley.*

1916 McEwen, Alfred.
Craig Avel, *Tarrytown-on-the-Hudson*, *New York*, *U.S.A.*

1894 Macintyre, John, M.B., C.M., F.R.S.E.
179, *Bath-street*, *Glasgow.*

1919 Mackay, Rev. A. F. Gordon.
Villamont, *Blue Ridge Springs*, *Virginia*, *U.S.A.*

1910 McKeever, Frederick Leonard
P.O. Box 210, *Penticton*, *British Columbia.*

1904 MacKenzie, John Ross, F.C.S.
Woodleigh, *Selborne-road*, *Barbourne*, *Worcester.*

1884 McMurrich, J. Playfair, M.A.
Anatomical Laboratory, *University of Toronto*, *Toronto*, *Canada.*

1919 Macpherson, Angus Duncan, M.B.
18, *Cornwall-mansions*, *Chelsea*, *S.W.*10

Elected.

1884 Mainland, George Edward.
14, *The Norton, Tenby, South Wales.*

1911 Mansfield-Aders, Walter, Ph.D.
Zanzibar, East Africa.

1909 Mapp, Charles Richard, B.Sc.
37, *Montpellier-terrace, Cheltenham.*

1920 Marchment, Reginald Henry.
10, *High-road, Wood Green, N.*

1896 Marshall, William John.
"*The Nook,*" 15, *Elms-road, Dulwich Village, S.E.*

1904 Mason, Francis Archibald.
29, *Frankland-terrace, Leopold-street, Leeds.*

1920 Maulik, Professor Samarendra, M.A., F.Z.S.
Zoological Laboratory, The University, Calcutta, India.

1892 Maw, William Henry, C.E., F.R.G.S.
18, *Addison-road, Kensington, W.*

1879 *Mercer, A. Clifford, M.D.
324, *Montgomery-street, Syracuse, N.Y., U.S.A.*

1899 Merlin, Augustus Alfred Cornwallis Eliot.
31, *Cleveland-gardens, West Ealing, W.*13

1914 Merriman, Captain Arthur D., M.A.
27, *Ashmore-road, King's Norton, Birmingham.*

1884 Mestayer, Richard Liron, M.Inst.C.E.
139, *Sydney-street, West Wellington, N.Z.*

1901 *Metheny, Samuel Alexander Sterrett, B.A., M.D.
617, *North Forty-third-street, Philadelphia, Pa., U.S.A.*

1877 Michael, Albert Davidson, F.L.S., F.Z.S., F.R.H.S.
The Warren, Studland, near Swanage, Dorsetshire. (*See Honorary Fellows.*)

1915 Milbank, Sidney Alexander, M.B.A.A.
14, *North-street, Bishop Stortford.*

1895 Millard, Edgar James, F.C.S.
35–42, *Charlotte-street, E.C.*2

1891 Miller, John Albert, M.Sc., Ph.D., F.C.S., *Chemist to the State of New York.*
44 *and* 45, *Lewis Block, East Swan-street, Buffalo, N.Y., U.S.A.*

1920 Mills, Albert Edward, F.C.S., M.P.S.
8, *George-street, Bath.*

1912 Mills, Frederick William.
Thornleigh, Edgerton, Huddersfield.

1907 Minns, John Edward, M.S.C.I.
32, *North-street, Taunton, Somersetshire, and* 5, *North Town-terrace, Taunton.*

1905 Moffat, Eliezer.
75, *High-street, Chatham.*

1911 Mond, Robert Ludwig, M.A., F.R.S.E., F.Inst.P., F.C.S., F.Ph.S., F.G.S., F.Z.S.
Combe Bank, Sevenoaks, Kent.

Elected.
1916 Moore, Professor Benjamin, M.A., D.Sc., F.R.S.
8, *Pembroke-villas, The Green, Richmond.*
1897 Moore, Harry, *Curator, Public Museum, Clifton-park, Rotherham.*
12, *Whiston-grove, Moorgate, Rotherham.*
1851 Moreland, Richard, M.Inst.C.E.
4, *Highbury-quadrant, Highbury, N.*5
1896 Moreton-Parry, Lewis.
163, *Oakfield-road, Everton, Liverpool.*
1918 Morrish, William J., M.D., etc.
"*Westleigh,*" *Thrale-road, Streatham-park, S.W.*16
1918 Mortimer, Hugh Hamilton.
15, *Mulgrave-road, Croydon.*
1913 Mosey, Hessay, M.I.H.
7, *Pond-street, Hampstead, N.W.*3
1915 Mosley, Frederick Ormrod.
University College, Reading, and "*Whernside,*" *Basingstoke-road, Reading.*
1914 Mumford, Major E. Moore, M.Sc.
75, *High-street, Chorlton-on-Medlock, Manchester.*
1919 Murray, James Alexander, M.D.
Director, Imperial Cancer Research Fund.
8, *Queen's-square, W.C.*1
1900 Murphy, Albert John, F.C.S.
2, *Dorset-square, N.W.*1

1914 Nall, Rev. George Herbert.
18, *Dean's-yard, Westminster, S.W.*1
1915 Naylor, George, F.B.O.A., F.I.O.
52, *Cavendish-place, Jesmond, Newcastle-on-Tyne.*
1890 *Nelson, Edward Milles.
Beckington, near Bath, Somersetshire.
1911 Noad, Lewis.
7, *King's Bench-walk, Temple, E.C.*
1899 Norman, Albert, L.R.C.P. and L.R.C.S. Edin.
35, *Coleherne-road, Earl's Court, S.W.*10

1920 Oakden, Charles H., F.R.P.S.
Hamilton House, W.C.
1887 Ochsner, A. J., Ph.D., M.D.
2106, *Sedgwick-street, Chicago, Ill., U.S.A.*
1883 Offord, John Milton.
8, *Culmington-road, West Ealing, W.*13
1907 Ogilvy, James Wilson.
18, *Bloomsbury-square, W.C., and* 21, *Ravensdale-mansions, Crouch-end, N.*

Elected.

1878 O'Hara, Lieut.-Colonel Richard.
West Lodge, Galway.

1919 Oppenheimer, Captain Frank, I.M.S., S.R., M.B., Ch.B.
c/o Messrs. Grindlay & Co., Bombay, India.

1897 Orueta y Duarte, Domingo de
Lagasca 116, *Madrid, Spain.*

1900 Oxbrow, Alfred William.
7, *Old Haymarket, Norwich.*

1879 Oxley, Frederick.

1912 Palmer, Henry, J.P., F.R.G.S.
"*Wall Nook,*" *Langley Park, Durham.*

1910 Palmer, Thomas Chalkley, *President of Delaware County Natural History Society, Vice-Director, Biological Section, Academy of Natural Sciences of Philadelphia.*
Media, Delaware Co., Penn., U.S.A.

1919 Parish, Rev. Herald.
191, *Stamford-street, Brooks's Bar, Manchester.*

1912 Parsons, Frederick A.
15, *Osborne-road, Stroud-green, N.*

1890 *Paterson, Mrs. Catherine Childs.
15, *Compayne-gardens, N.W.*6

1916 Patterson, Capt. William R., F.R.A.S., F.R.G.S., F.R.A.I., F.R.C.I., M.R.A.S., F.R.Met.Soc., M.C.P.

1907 Paulson, Robert, F.L.S.
Glenroy, Cecil-park, Pinner, Middlesex.

1898 Payne, Arthur E. T.
Physiological Laboratory, University of Melbourne, Victoria, and Scotsburn, Toorak, Melbourne, Victoria.

1884 *Peek, The Honourable Lady.
Widworthy Court, Honiton.

1898 Pillischer, Jacob.
88, *New Bond-street, W.*1

1911 Pinchin, Ernest Alfred, B.Sc. (Lond.), F.I.C.
4, *Gleneldon-road, Streatham, S.W* 16

1906 Plaskitt, Frederick James Wade.
15, *Uxbridge-road, Rickmansworth, Herts.*

1907 Pledge, John Harry.
72, *Nibthwaite Road, Harrow, Middlesex.*

1919 Poignand, Rev. Cecil W., M.A.
c/o The Admiralty, London, S.W.

1897 Pollard, Jonathan.
10, *Porteus-road, Paddington-green, W.*2

1902 Poser, Max.
16, *Vick Park B., Rochester, N.Y., U.S.A., and c/o Bausch & Lomb, St. Paul-street, Rochester, N.Y., U.S.A.*

1867 Potter, George.
296, *Archway-road, N.*6

Elected.

1919 Pougher, Ernest W., M.M.A.E.
93, Manchester-road, Chorlton-cum-Hardy, Manchester.

1892 Pound, Charles Joseph.
Director, Stock Experiment Station, Yeerongpilly, Queensland, Australia.

1880 Powell, Thomas Hugh.
Emsdale, Greenham-road, Muswell-hill, N.

1898 Radley, Percy Edward, F.Z.S.
Nesta, Broxbourne, Herts, and The Metric Publishing Co., 329, High Holborn, W.C.1

1919 Ramana-Sāstrin, Vedāranyešvara Vaidyanātha, M.A., Ph.D., F.L.S., F.Z.S., F.R.H.S., F.R.A.S., F.R.Met.Soc., F.P.S.L., Mem. Brit. Astron. Ass., Mem. Royal Astron. Soc. of Canada, Mem. London Math. Soc., M.R.A.S.
Vedaraniam, Tanjore, Dt., South India, and 1, Sami Pillai-street, Choolai, Madras, N.C., South India.

1896 Ranken, Charles, F.C.S.
11, Stockton-road, Sunderland.

1920 Rau, Venkata, M.A.
Department of Agriculture, Bangalore, India, and c/o Messrs. Coutts & Co., Bankers, Strand, W.C.

1917 Rawlins, Francis Ian Gregory.
White Waltham Grove, near Maidenhead, Berkshire.

1912 Rees, W. Eric, F.S.M C.
Clovelly, Bedford-road, Newport, Mon.

1910 Reid, Alfred, M.B., D.P.H., B.Hy. Durh., M.R.C.S. Eng., L.R.C.P., *Government Medical Officer.*
Kuala Lumpur, Selangor, Federated Malay States.

1920 Reid, Duncan James, M.B., C.M.
20, Blakesley-avenne, Ealing, W.5

1897 Remington, John Stewart, M.R.A.C., F.C.S., F.L.S.
Aynsome-house, Grange-over-Sands, R.S.O., Lancashire

1899 Rheinberg, Julius.
23, The Avenue, Brondesbury-park, N.W.

1893 Richardson, Frederic William, F.I.C., F.C.S., *County Analyst, Bradford, and Oak Lea, Menston, Yorkshire.*

1916 Richardson, John.

1908 Robertson, James A.
Skerryvore, Holmfield-avenue, Cleveleys, near Blackpool.

1910 *Robins, Herbert George, F.R.G.S.
Toms Farms, Wankie, S. Rhodesia, South Africa.

1917 *Robinson, Miss Nancy M.
Glassel House, Glassel, Aberdeenshire.

1899 Rogers, George Henry James.
2, Bower-terrace, Tonbridge-road, Maidstone.

1911 Ross, John Pilkethly, M.P.S.
Care of Messrs. Stella and Co., Esplanade-road, Bombay, India.

Elected.
1918 Ross, Sydney W.
Michelmersh, Romsey, Hants.
1883 *Rosseter, Thomas B.
6, *Salisbury-road, St. Stephen's, Canterbury.*
1888 Rousselet, Charles Frédéric.
15, *Cloudesley-road, St. Leonards-on-Sea.*
1918 Rowley, Frank, M.I.M.M.
21, *Buckland-crescent, Hampstead, N.W.3*
1897 Rowley, Frederick Richard, *Curator, Royal Albert Memorial Museum, Exeter.*
8, *Pinhoe-road, Heavitree, Exeter.*
1917 Ryland, Lieut.-Colonel Alfred W.
Glen Hurst, Watling-street-road, Fulwood, Preston.

1919 St. John-Ward, Henry.
Brebner School, Bloemfontein, Orange Free State, South Africa.
1918 Salmon, Walter.
17, *The Grove, Eccles, Lancs.*
1892 *Salomons, Sir David Lionel, Bart., J.P., M.A., D.L., F.R.G.S., F.G.S., F.Z.S.
49, *Grosvenor-street, W.; and Broomhill, Tunbridge Wells.*
1909 Saxton, Thomas R., Assoc.M.Inst.C.E.
43, *East Bank, Stamford-hill, N.*16
1898 Scales, F. Shillington, M.A., M.D., B.C. (Cantab.).
Redcourt, Adams-road, Cambridge.
1880 Scott, Dukinfield Henry, M.A., D.Sc., Ph.D., LL.D., F.R.S., F.L.S.
East Oakley-house, Basingstoke, Hants, and Athenæum-club.
1916 Scott, Joseph Henry.
2, *Priory-gardens, Weld-road, Birkdale, Southport.*
1909 Scott, Walter.
Nant-y-Coed, Conway, Carnarvonshire.
1913 Scott, Wm., F.R.C.V.S.
Friarn House, Bridgwater.
1900 Scourfield, David J., F.Z.S., Hon. Secretary.
63, *Queen's-road, Leytonstone, E.*11
1907 Scriven, Charles R.
Kingscote, Furze-hill, Burgh-heath, Surrey.
1919 Seager, John Horsford.
1, *St. Mary's-road, Faversham, Kent.*
1917 Sears, R. S. W.
1, *Lisson-grove, Marylebone, N.W.*1
1918 Seymour-Jones, Alfred.
"*Pendower,*" *Wrexham.*
1902 Sharpe, Charles James.
130, *Fenchurch-street, E.C.*3

Elected.

1885 *Shelley, Major A. D. G., R.E. (Retired).
*Bombay, Baroda and Central Indian Railway Board, 11, Bishopsgate, E.C.*2

1910 Sheppard, Alfred William, F.L.S.
"Royal Oak" Hotel, Sevenoaks.

1909 Sheppard, Edward James.
137, *Kennington-road, Lambeth, S.E.*11

1920 de Sibour, Le Vicomte, F.Z.S.
c/o Messrs. Morgan Grenfell & Co., 22, *Old Broad-street, E.C.*

1909 Sidwell, Clarence J. H.
46, *Ashbourne-grove, East Dulwich, S.E.*

1912 Simpson, Norman Douglas, B.A.
Maesbury, Cavendish-road, Bournemouth.

1916 Singer, Charles, M.A., M.D.
Westbury Lodge, Norham-road, Oxford.

1910 Sinha, J. C., J.P., Honorary Presidency Magistrate.
c/o Jones & Co., Solicitors, 6, *Old Post Office-street, Calcutta.*

1918 Skepper, Harry Godfrey.
"Lindum," Brothertoft-road, Boston, Lincs.

1917 Smith, Joseph, F.S.A.A.
28, *Altom-street, Blackburn, Lancashire.*

1908 Smith, Theodore White.
Naperville, Du Page County, Illinois, U.S.A.

1906 Smith, Thomas James.
Braeside, Bosworth-road, New Barnet.

1897 Soar, Charles David, F.L.S.
37, *Dryburgh-road, Putney, S.W.*15

1920 Sonntag, Charles F., M.D., Ch.B.
80*a*, *Belsize-park-gardens, N.W.*3

1903 Spitta, Edmund Johnson, L.R.C.P. (Lond.), M.R.C.S., (Eng.), F.R.A.S.
41, *Ventnor-villas, Hove, Brighton.*

1918 Springall, Hubert F.
The Friars, King's Lynn.

1903 Spry, Robert, Lieut.-Commander, R.N.
83, *Mount-Gold-road, Plymouth.*

1882 Squance, Major Thomas Coke, M.D., M.S., F.R.S.E.
The Cottage, Newbiggin, Aysgarth, S.O., Yorks.

1909 Stewart, Thomas S., M.D.
1736, *Spruce-street, Philadelphia, Pa., U.S.A.*

1900 Stiles, Matthew Henry.
10, *Avenue-road, Doncaster.*

1867 Stoker, George Naylor.
Fairfield, Lessar-avenue, Clapham-common, S.W.

1914 Strachan, James.
74, *Blenheim-place, Queen's Cross, Aberdeen.*

1912 *Stringer, Edward Belcher.
Egerton-lodge, Bromley, Kent.

Elected

1871 Stuart, John.
3, *North-side, Clapham-common, S.W.*4

1918 Sutcliffe, Herbert.
The Research Laboratory, Petaling, Federated Malay States.

1920 Sutherland, Donald, M.A.
"*Golden Hurst*," 20, *Carmunnock-road, Cathcart, Glasgow.*

1919 Swainson-Hall, R., F.L.S.
Poste Restante, Casa de Senor Joao Martins, Cabinda, Portuguese Congo, S. W. Africa.

1906 Swift, Mansell James.
81, *Tottenham-court-road, W.*1

1889 Sykes, Mark Langdale.
95, *Cardigan-road, Leeds.*

1911 Syner, Harry.

1911 Tabor, Charles James, F.R.A.I.
The White House, Knott's-green, Leyton, Essex.

1891 *Talmage, James Edward, D.Sc., Ph.D., F.R.S.E., F.G.S., *Professor of Geology, University of Utah, Salt Lake City, Utah, U.S.A.*
The Deseret Museum, Salt Lake City, Utah.

1900 Taverner, Henry.
Wrekin House, 319, *Seven-Sisters-road, Finsbury-park, N.*4

1919 Taylor, Albert.
32, *William-street, Ryecroft, Ashton-under-Lyne.*

1915 Taylor, Frederick H.
County Bank, Chorley, Hants.

1891 Terry, Edwin, F.C.S.
Sunbury House, 374, *Brixton-road, S.W.*9

1916 Thirunal Raja, Rohani, M.R.A.S.C., M.S.S.A., M.A.S.P., etc., etc.
Kizhakke Kottaram Palace, Trivandrum, Travancore, S. India.

1885 *Thomson, J. Arthur, M.A., LL.D., F.R.S.E., F.Z.S., *Regius Professor of Natural History in the University of Aberdeen.*
Natural History Department, Marischal College, University, Aberdeen, and Castleton House, Old Aberdeen.

1881 Thomson, William.
Royal Institution Laboratory, 79A, *Princess-street, Manchester.*

1920 Thorne, Captain Ralph G. A., B.A.
82, *Ashley-gardens, S.W.*1

1912 Tierney, Clarence, M.S., D.Sc.
"*Netherton*," *Coulsdon, Surrey.*

1901 Tilling, George.
*Grasmere, Rydal-road, Streatham, S.W.*16

Elected.

1919 Tomlinson, Thomas Willis Brown.
High-street, Berkhamsted.

1919 Topley, William Whiteman Carlton, M.D., F.R.C.P., M.R.C.S., etc.
*The Institute of Pathology, Charing Cross Hospital Medical School, Chandos-street, W.C.*2

1918 Triggs, Edward E.
c/o Marconi Co., Milburn House, Newcastle-on-Tyne.

1920 Trinder, George A. W., M.J.I.
471, *Harrow-road, W.*10.

1917 Tripp, Charles Llewellyn H., M.R.C.S., L.R.C.P.
The Chestnuts, Staplegrove, Taunton.

1919 Tucker, Quincey C., M.B., Ph.G.
U.S. Naval Hospital, Fort Lyon, Colorado, U.S.A.

1920 Turner, William.
21, *Vera-road, Fulham, S.W.*

1915 Tutt, Captain John Francis Donald, M.R.C.V.S., F.Z.S.
1, *St. Cross-road, Winchester.*

1882 Tuttle, Albert Henry, M.Sc.
University of Virginia, Charlottesville, Va., U.S.A.

1913 Verrall, Frederick H., B.A., LL.B.
The Hollies, Worthing, Sussex.

1909 Walter, Rev. Frederick William.
The Grange, Worstead, Norfolk.

1867 *Walters, James Hopkins, M.R.C.S.
15, *Friar-street, Reading.*

1869 Ward, Frederic Henry, M.R.C.S.
52, *Lancaster-road, West Norwood, S.E.*27

1885 Warner, Edmond.
Southend House, Eltham, S.E.

1911 Warrington, Capt. A. F. G., F.R.G.S.
c/o The British India Marine Service Club, Norton's-buildings, Calcutta, India.

1883 Waters, Arthur William, F.L.S., F.G.S.
Alderley, McKinley-road, Bournemouth.

1919 Watkinson, Harry.
348, *Hainton-avenue, Grimsby.*

1919 Watts, George William, L.D.S.Eng.
103, *Haverstock-hill, N.W.*3

1912 Webb, Wilfred Mark, F.L.S.
The Hermitage, Hanwell, W.

1897 Webster, William Thomas.
252, *Caledonian-road, N.*1

1920 Welsford, Miss Evelyn Janie, M.B.E., F.L.S.
Horticultural College, Swanley, Surrey.

Elected.

1885 *Western, Edward Young.
27, *Pembridge-square, Notting-hill-gate, W.*3

1919 Whipp, James Ewart, M.P.S.
15, *St. John-street, Longsight, Manchester.*

1895 White, Charles Powell, M.D., F.R.C.S., L.R.C.P., *Pathological Department, Victoria University, Manchester.*
1, *Albemarle-road, Withington, Manchester.*

1886 *Whitehead, Ralph Radcliffe.
Woodstock, Ulster C., N.Y., U.S.A.

1898 Whittaker, Oscar, F.E.S.
"*Ormidale,*" *Ashlands, Ashton-upon-Mersey, Cheshire.*

1915 Whitteron, Frederick.
78, *Barkly-street, St. Kilda, Melbourne, Victoria, Australia.*

1913 Wigan, Basil P., F.C.S.
Rhondda-valley Breweries Co., Treherbert, S. Wales.

1910 Wilding, Percy P.
Fern Nook, Penwortham Hill, Preston, Lancs.

1916 Wilkin, Lieutenant Arthur P., F.R.H.S., F.Z.S., F.R.B.S.
c/o Eastern Telegraph Co., Ltd., Bombay, India.

1908 Wilson, Joseph.
The Hawthorns, 3, *West-park-road, Kew-gardens, S.W.*

1911 Wilton, Edmund Wade, A.I.S.E., F.S.A.
Planet Works, Bramley, Leeds, and Cliff View, Pollard-lane, Newlay, near Leeds.

1909 Winton, Francis Langridge, M.A.
The Brewery, Chatteris, Cambs., and 23, *Bateman-street, Cambridge.*

1911 Woodhead, Sir German Sims, K.B.E., M.A., M.D., LL.D., F.R.S.E., F.R.C.P. (Ed.), *Professor of Pathology in the University of Cambridge.*
Dysart House, Luard-road, Cambridge.

1880 *Woodward, Bernard B., F.L.S., F.G.S.
4, *Longfield-road, Ealing, W.*5

1880 *Woodward, Henry, LL.D., F.R.S., F.G.S., F.Z.S.
Tudor Cottage, Clay Hill, Bushey, Herts.

1889 Wright, Charles Henry.
10, *Clarence-road, Kew.*

1882 Wright, Prof. R. Ramsay, M.A., B.Sc.
Red Gables, Headington-hill, Oxford.

1919 Wycherley, Sydney R.
25, *Hollegrave-road, Bromley, Kent.*

1918 Yermoloff, Sir N., K.C.B., K.C.V.O., F.L.S.
3, *Whitehall-court, S.W.*1

1890 *Youdale, William Henry.
21, *Belle Isle-street, Workington.*

Elected.
1918 Young, George William.
20, Grange-road, Barnes. S.W.

1904 Zimmerman, Professor Charles, F.R.M.S.
Sao Carlos de Pinhal, Rua 13 *de Maio*, 60, *Estado de S. Paulo, Brazil.*

HONORARY FELLOWS.

1879 Balbiani, E. G.
Paris.
1904 Bonnier, G.
Paris.
1918 Bruce, Lady Mary Elizabeth, R.R.C.
London.
1904 Delage, Y.
Paris.
1895 Golgi, C.
Padua.
1905 Jennings, H. S.
Baltimore.
1897 Lee, A. B.
Cologny.
1919 Michael, Albert Davidson, F.L.S., F.Z.S., F.R.H.S.
Studland.
1912 Penard, Eugene.
Geneva.
1904 Ramón y Cajal, S.
Madrid.
1879 Ranvier, L.
Paris.
1879 Sars, G. O.
Christiania.
1904 Teall, J. J. H.
London.
1897 Toni, G. B. de
Modena.
1879 Warming, E.
Copenhagen.
1905 Wilson, E. B.
New York.
1905 Wood, R. W.
Baltimore.

Patron.

HIS MAJESTY THE KING.

Past-Presidents.

	Elected
*Sir Richard Owen, K.C.B., D.C.L., M.D., LL.D., F.R.S.	1840–1
*John Lindley, Ph.D., F.R.S.	1842–3
*Thomas Bell, F.R.S.	1844–5
*James Scott Bowerbank, LL.D., F.R.S.	1846–7
*George Busk, F.R.S.	1848–9
*Arthur Farre, M.D., F.R.S.	1850–1
*George Jackson, M.R.C.S.	1852–3
*William Benjamin Carpenter, C.B., M.D., LL.D., F.R.S.	1854–5
*George Shadbolt	1856–7
*Edwin Lankester, M.D., LL.D., F.R.S.	1858–9
*John Thomas Quekett, F.R.S.	1860
*Robert James Farrants, F.R.C.S.	1861–2
*Charles Brooke, M.A., F.R.S.	1863–4
*James Glaisher, F.R.S.	1865–6–7–8
*Rev. Joseph Bancroft Reade, M.A., F.R.S.	1869–70
*William Kitchen Parker, F.R.S.	1871–2
*Charles Brooke, M.A., F.R.S.	1873–4
*Henry Clifton Sorby, LL.D., F.R.S.	1875–6–7
*Henry James Slack, F.G.S.	1878
*Lionel S. Beale, M.B., F.R.C.P., F.R.S.	1879–80
*Peter Martin Duncan, M.B., F.R.S.	1881–2–3
*Rev. William Henry Dallinger, M.A., LL.D., F.R.S.	1884–5–6–7
*Charles Thomas Hudson, M.A., LL.D. (Cantab.), F.R.S.	1888–9–90
*Robert Braithwaite, M.D., M.R.C.S.	1891–2
Albert D. Michael, F.L.S.	1893–4–5–6
Edward Milles Nelson	1897–8–9
William Carruthers, F.R.S., F.L.S., F.G.S.	1900–1
Henry Woodward, LL.D., F.R.S., F.G.S., F.Z.S. ..	1902–3
Dukinfield Henry Scott, M.A., Ph.D., LL.D., F.R.S., F.L.S.	1904–5–6
*The Right Hon. Lord Avebury, P.C., D.C.L., LL.D., F.R.S., etc.	1907–8
Sir Edwin Ray Lankester, K.C.B., M.A., LL.D., F.R.S., F.L.S., F.Z.S.	1909
J. Arthur Thomson, M.A., F.R.S.E.	1910–11
*Henry Geo. Plimmer, F.R.S., F.L.S., F.Z.S., etc. ..	1911–12
G. Sims Woodhead, M.A., M.D., LL.D., F.R.S.E., etc. ..	1913–15
Edward Heron-Allen, F.R.S., F.L.S., F.G.S., etc. ..	1916–17
Joseph E. Barnard, F.Inst.P.	1918–19

* Deceased.

JOURNAL

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MARCH, 1920.

TRANSACTIONS OF THE SOCIETY.

I.—*Studies on the Binucleate Phase in the Plant-cell.* *

By Agnes Arber, D.Sc., F.L.S., Keddey Fletcher-Warr Student of the University of London.

(*Read February* 18, 1920.)

One Plate and Two Text-figs.

Introduction.

In a recent paper, by Mr. Rudolf Beer and the present writer, in the Proceedings of the Royal Society,† attention has been drawn to the occurrence of binucleate or multinucleate cells in the young vegetative tissues of 177 species, representing 60 families, and including members of the Pteridophytes, Gymnosperms, Dicotyledons and Monocotyledons. The binucleate condition, which in these cases occurred *as a normal feature,* was invariably found to arise through mitosis, and not by direct division. It was shown that, though the cell-plate makes its appearance as usual, it fails to give rise to any cell-membrane, while the whole complex of spindle fibres with the associated cytoplasm becomes transformed into a hollow sphere which encloses the daughter nuclei. For this spherical shell we have suggested the term "phragmosphere." The phragmosphere is seen in section in a number of the examples drawn on the plate accompanying the present paper (see, for instance, figs. 7, 26 and 39 A). In the memoir cited we enume-

* The writer desires to acknowledge her indebtedness to the Senate of the University of London for a grant from the Dixon Fund towards the expenses of tihs and other researches.

† Beer, R. and Arber, A. (1919) and (1915).

rated many cases in which these phenomena had been observed, but we did not describe them individually. In the present instalment I propose to deal with the history of the vegetative nucleus, so far as this history bears upon the binucleate phase, in the following species, each of which has been chosen as presenting certain features of interest :—

1. *Eremurus himalaicus* Baker (Pl. I, figs. 1–11, and pp. 2–6).
2. *Asparagus officinalis* L. (Pl. I, figs. 13, 27, 28, and pp. 6–11).
3. *Helianthus Nuttallii* Torr. et Gray (Pl. I, figs. 21–24, and pp. 11–12).
4. *Helianthus tuberosus* L. (pp. 12–13).
5. *Syringa vulgaris* L. (p. 13).
6. *Monstera deliciosa* Liebm. (Pl. I, figs. 39 A and B, and p. 14).
7. *Hemerocallis fulva* L. (Pl. I, figs. 33–37, and pp. 14–15), *Nothoscordum fragrans* Kunth (p. 15), and *Alisma Plantago* L. (Pl. I, fig. 38, and p. 15).
8. *Polygonum cuspidatum* Sieb. et Zucc. (Pl. I, figs. 25 and 26, and pp. 15–16).
9. *Morus nigra* L. (Pl. I, figs. 12 A–C, and pp. 16–18).
10. *Hippuris vulgaris* L. (Pl. I, figs. 17–20, and pp. 18–19), and *Elodea canadensis* Michx (Pl. I, figs. 29–32, and p. 19).
11. *Stratiotes aloides* L. (Text-figs. 1 and 2, and pp. 19–21).

1. *Eremurus himalaicus* Baker (Pl. I, figs. 1–11).

Eremurus himalaicus is a large and vigorous member of the Liliaceæ, which throws up in the spring a rapidly-growing raceme of numerous flowers, sometimes attaining the height of 6 feet or more by the middle of June. The developing inflorescence axis affords very favourable material for the study of the binucleate phase. A transverse section of the axis in the flowering region reveals a broad vascular zone enclosing a small central pith, the whole surrounded by a narrow parenchymatous cortex. Such a section, examined while the inflorescence is quite immature (e.g. in the latter part of April), shows that the great majority of the cells of the pith and the ground tissue between the bundles contain two nuclei, or in some cases as many as three. Binucleate cells also occur, though more rarely, in the cortex, which consists of elements of smaller diameter than those of the pith and ground tissue. The epidermis appears to be entirely uninucleate. A study of the origin of the supernumerary nuclei shows that they invariably arise by mitosis. The cells contain vacuolate cytoplasm. When a nucleus is about to divide the cytoplasm appears to be attracted towards it, and it becomes suspended from the lining layer by more numerous, conspicuous and well-defined bridles than in the case of those nuclei which are in a condition

of complete rest (Pl. I, fig. 1). The same aggregation of cytoplasm has been noticed in the case of *Dipsacus laciniatus.* In some preparations of the prothallus of *Cephalotaxus Fortunei*, at the stage when the cells are becoming multinucleate, which Mr. Boodle has kindly shown to me, the relation of the cell protoplasm to the dividing nuclei is exactly similar to that just described for *Eremurus*, the cytoplasmic bridles being particularly well developed.

The formation of binucleate cells proceeds exactly on the lines described in general terms in the paper already cited.* While the daughter nuclei are passing into rest, the chromosomes go through a stage in which they each show a large vacuole (Pl. I, figs. 8 and 9). That such paired nuclei retain the power of further division is shown by the fact that a phragmosphere, with its two included nuclei, may be accompanied, in the same cell, by a resting nucleus (Pl. I, fig. 7). This indicates that the cell previously enclosed a pair of nuclei, one of which has divided again, while the other has remained in the resting condition. This is of some interest, since it means that two sister nuclei, necessarily of identical age and living apparently under identical conditions within a single vegetative cell, are yet capable of showing marked individuality in their behaviour.

In the previous generalized account of the development of the phragmosphere (l.c. p. 10), it is stated that a cell-plate is formed but disappears later. It may, however, be objected that when two daughter nuclei are observed with a cell plate between them (as in Pl. I, fig 4) there is no proof that the development of a phragmosphere will follow, since the appearance in question might equally well be interpreted as an early stage in actual cell-wall formation. The conclusion that such stages are both *bona fide* members of the phragmosphere series is based on the fact that in the inflorescence described there is no evidence of any recent wall formation in planes parallel to the long axis of the organ; a cell plate such as that figured could form a wall in such a plane only. The cells both of the pith and of the ground tissue between the bundles have a rounded outline, as seen in transverse section, and intercellular spaces occur between them. This is true of all the inflorescences studied, even the very young one to which attention will be called shortly. The only exception is found in certain small cells in the pith which contain raphides and mucilage, and which divide fairly frequently. But these cells are quite distinct in their characters, and the occurrence of wall formation in them does not affect our argument; our figures and descriptions refer to the normal pith and ground tissue, and not to these specialized cells. In order to test the contention that the increase in diameter of the axis depends

* Beer, R. and Arber, A. (1919) p. 10.

mainly, if not entirely, upon increase in size of the cells without cell division, measurements were made of the dimensions in transverse section of ten pith cells taken at random from the extreme bases of the inflorescences gathered on February 9 and April 27 respectively. The pith cells in the former case were found to average 58 μ and in the latter 73 μ in diameter, which represents an increase of 26 p.c. The entire axis had increased in the same period from approximately 6 mm. to 7·5 mm. in diameter, representing an increase of 25 p.c. As there is much variation in size in the pith cells, no great reliance can be placed upon the exact figure obtained for their average diameter, and the extremely close coincidence of these percentages is probably more or less accidental; but we may at least conclude that in the case of the pith the stretching of already existing cells is competent to account for the increase of diameter, and that no appreciable amount of cell multiplication, with formation of cell walls in planes parallel to the long axis of the organ, need be postulated.

In describing the binucleate phase in the inflorescence gathered on April 27, we have so far been considering only the main part of the flowering region. Binucleate cells occur near the apex, but this is not a favourable case for studying the exact point at which this condition arises, since the tip becomes hollow and dies at a relatively early period. Passing to the lower sterile region of the inflorescence axis, we find that binucleate cells no longer occur, but the single nuclei are bilobed or irregularly lobed.

For comparison, older and younger inflorescences were studied. A very young inflorescence was dissected out of the terminal leaf-bud early in February. The flowering region was about 2·5 cm. long, and the sterile stalk not more than 2 cm. Binucleate cells and phragmospheres occurred in the fertile region, just as in that gathered at the end of April. In this young inflorescence, however, phragmospheres were not confined to the fertile region, but occurred, in addition, in the sterile stalk.

Two older inflorescences, gathered on May 7 and May 28 respectively, were also studied. On examining the fertile region of the inflorescence fixed on May 7, it was found that, though many cells of the pith and ground tissue were binucleate, as in the younger axes, nuclear division had apparently ceased and many of the cells had become uninucleate. The nuclei within the uninucleate cells were often neatly bilobed, but sometimes lobed or fissured in an irregular fashion, thus recalling the condition in the sterile lower region in the inflorescence axis fixed ten days earlier (Pl. I, fig. 10). In the axis gathered on May 28 uninucleate cells had become still more universal, and the lobing was as pronounced as in the previous case. In both these axes the nuclei appeared somewhat flattened when seen in profile. The bilobing of the nuclei was so frequent and striking that its occurrence in cells

which must have been binucleate at an earlier stage immediately suggested that it was an indication of nuclear fusion. This view we were at first inclined to accept, but further work has led to the conclusion that it is probably untenable. The converse view, that these lobings might represent early stages in amitotic division, is at once put out of court by the fact that this stage *follows* the binucleate stage instead of *preceding* it. Light is thrown upon the subject by a careful examination of the fertile region of the inflorescence axis gathered on April 27. Here we find a number of instances in which one nucleus in a cell looks more or less normal, while the other stains homogeneously and is apparently degenerating (Pl. I, fig. 11). Such evidence has, naturally, to be used with great caution to avoid confusing the results of poor fixation with actual degeneration stages, especially when considering resting nuclei, which are often less well preserved than those in process of division. It seems improbable, however, that we are dealing with an artefact in the present case, since in the same section phragmospheres and well-preserved nuclei, both in the resting stage and various mitotic phases, may be observed. One apparently degenerating nucleus and one in the prophase of division have been noted in a single cell. However, though dividing nuclei in all stages are well preserved in our material of this species, the preservation of the resting nuclei is throughout less satisfactory, and the possibility must be recognized that our "degenerations" are artefact.

That one of two sister nuclei of identical age and history in the same cell should degenerate while the other remains normal is perhaps a somewhat unexpected result, but, as we have already shown (p. 3), there is no doubt that, at earlier stages, such pairs may show differential behaviour, one entering upon a second division, while the other remains in the resting stage. We are, on the whole, inclined to think that the ultimate uninucleate condition is brought about by the degeneration and resorption of one nucleus, while the later lobing, whether regular or irregular, is merely a symptom of age and perhaps partial degeneracy. The large-sized nuclei of the Liliaceæ must naturally be more liable to collapse and become irregular in outline than smaller and more compact nuclei, such as are generally met with among the Dicotyledons. We do not, however, consider that the possibility of an occasional fusion is excluded; the close approximation in which the pairs of nuclei sometimes lie seems favourable to such an event.

In order to find out whether the cytological features observed bore any relation to the rates of elongation of the different regions, two inflorescences were chosen at the end of April and their axes were marked off with indian ink into zones 1 c.m. in length; the increase in length of these zones was recorded week by week in the period before fixation. A single example will suffice to show the

result of the examination of the nuclei in these zones, whose growth-history was known. Sections were cut from two regions of an inflorescence axis gathered on May 28th, one of which had not increased in length at all, while the other showed the greatest increase observed in any zone in this particular week—namely, an elongation of from 2·8 to 5·5 cms., or nearly 100 p.c.* It was found that in both these cases the nuclei showed the same characteristics; most of the cells were uninucleate and many of the nuclei were bilobed. In general, the conclusion to be drawn from the different inflorescences which came under observation seems to be that the binucleate stage in which phragmospheres are abundant is characteristic of the inflorescence in its younger state, while the period of greatest elongation, which occurs subsequently, is marked by the presence of single nuclei, often much lobed and flattened, whose appearance suggests senility. These nuclei seem to remain in much the same condition after the cessation of growth.

Besides the inflorescence axes, very young leaves gathered in February were examined. They showed binucleate cells and phragmospheres in the mesophyll of their basal centimetre, while near the apex few nuclei were visible at all, and binucleate cells were apparently absent. The results obtained from the leaf thus harmonized with those just recorded for the inflorescence, bearing in mind that the basal region, in the leaves of this type among the Liliaceæ, is the growing zone.

2. *Asparagus officinalis* L. (Pl. I, figs. 13, 27, 28).

The young shoots of Asparagus, examined in the early part of May, at the stage at which they are usually cut for market, show the binucleate phase very clearly. Sections across the "head" reveal the presence of binucleate and sometimes trinucleate or even quadrinucleate parenchyma cells in the pith, in the ground tissue between the scattered bundles, and in the cortex.† Binucleate cells may also be observed, though rarely, in the xylem parenchyma bordering the young vessels, and in the epidermis. The paired nuclei arise by karyokinesis, the process of division and the formation of phragmospheres occurring precisely as described for the case of *Eremurus*. *Asparagus* is less well adapted than *Eremurus* for the study of the various stages leading up to phragmosphere formation, because, side by side with the production of binucleate cells, wall formation is going on on a considerable scale, in planes both parallel and perpendicular to the axis. The result is that it

* These measurements are only approximately accurate, since the growth of the axis had stretched and blurred the indian ink marks.

† Beer, R. and Arber, A. (1919), Text-figs. 1 and 2, p. 9.

is impossible to say, when a nucleus is observed in the act of division, whether it will ultimately give rise to paired nuclei in a single cell or to the solitary nuclei of two sister cells. It is interesting to observe that the nuclei of cells which are adjacent, or almost adjacent, may divide simultaneously, one giving rise to paired nuclei enclosed in a phragmosphere, while the other produces two nuclei whose phragmoplast deposits a new cell wall in a perfectly normal fashion.

The parenchyma cells of the pith and ground tissue are relatively large and vacuolate, and, as usual in such cases, the wall formation occurs by the "progressive" method first described by Treub *—the two nuclei and the phragmoplast travelling across the cell in order to carry the new cell wall over the entire area. The cell figured on Pl. I, fig. 27, shows this point, and also illustrates the fact that a pair of free nuclei may be formed within a single cell, and that one may subsequently divide into two daughter nuclei which become separated by a cell wall. A similar occurrence has been described by Němec † in the case of the multinucleate plerome elements of *Ricinus*, but he mentions that it is extremely rare. This wall formation between the daughters of a nucleus which was itself "free" shows that the appearance of binucleate cells cannot be taken to indicate that the power of initiating wall formation is actually lost; it should rather be regarded as being in abeyance.

The fact that in the stem of *Asparagus* wall formation is actively continued to some little distance below the apex is perhaps connected with the existence of a subsequent period of extremely rapid cell stretching and elongation. This point may be illustrated by some actual measurements. A shoot whose above-ground portion was 6·3 cm. long on May 12 increased in a week to 18·3 cm., thus almost trebling its length, but remaining unbranched. In the next week (May 19 to 26) it not only increased to 84 cm.—adding, that is to say, 65·7 cm. to its stature —but also threw out branches from the axils of all the upper leaves; the lowest of these branches was 18 cm. long, or about as tall as the entire main axis of a week ago! Such rapid growth must be very largely a matter of the elongation of already existing cells, so it is not surprising that the *Asparagus* shoot prepares itself by a good deal of preliminary wall formation. After this great growth has taken place, and the short, thick *Asparagus* shoot has become slender and branched, binucleate cells may still be observed near the apex, showing that this character is not confined to the very young stages.

The distance from the apex at which the binucleate phase begins to make its appearance was determined by means of serial

[*Contd. on p.* 10.

* Treub, M. (1879).

† Němec, B. (1910).

EXPLANATION TO THE PLATE.

All figures, unless otherwise stated, drawn with the camera lucida from transverse hand sections of the organs in question. Zeiss 2-mm. oil-immersion lens and C.O. 6 used throughout. Magnification 1070, reduced in reproduction to about 460.

Figs. 1–11.—*Eremurus himalaicus* Baker.

Figs. 1–9 illustrate phragmosphere formation in the ground tissue cells of a young inflorescence axis at the stage reached towards the end of April or beginning of May.

Fig. 1.—Binucleate cell in which one nucleus is about to divide again (to economize space outline of cell incompletely shown).

,, 2.—Chromosomes on equatorial plate.

,, 3.—Spindle with chromosomes at the poles, from a cell which also contained a resting nucleus.

,, 4.—Initiation of cell plate.

Figs. 5, 6.—Early stages in phragmosphere formation.

Fig. 7.—A phragmosphere with paired nuclei, in a cell also containing a resting nucleus.

,, 8.—Phragmosphere expanding towards the wall of the cell; chromosome of daughter nuclei becoming vacuolate.

,, 9.—Phragmosphere coinciding with the cytoplasm lining the cell wall.

,, 10.—Nuclei from uninucleate cells just below flowering region in an inflorescence somewhat older than that from which the majority of figs. 1–9 were drawn (gathered May 7, 1915).

11.—A normal nucleus (*n*) and a degenerating nucleus (*d*) belonging to the same cell (April 27, 1915). The nuclei were not in contact, but lay in different focal planes.

Figs. 12 A–C.—*Morus nigra* L. May 8, 1916.

Fig. 12 A.—Spindle in the corner of a large pith cell. (To economize space the outline of the cell is only shown in part.)

,, 12 B.—Pith cell, with a phragmosphere enclosing two daughter nuclei.

,, 12 C.—Phragmosphere at a late stage, in a pith cell.

Fig. 13 (see also figs. 27, 28)—*Asparagus officinalis* L. May 6, 1915.

Lobed nuclei, from five uninucleate cells of ground tissue between 2·5 and 4·5 cm. below base of head.

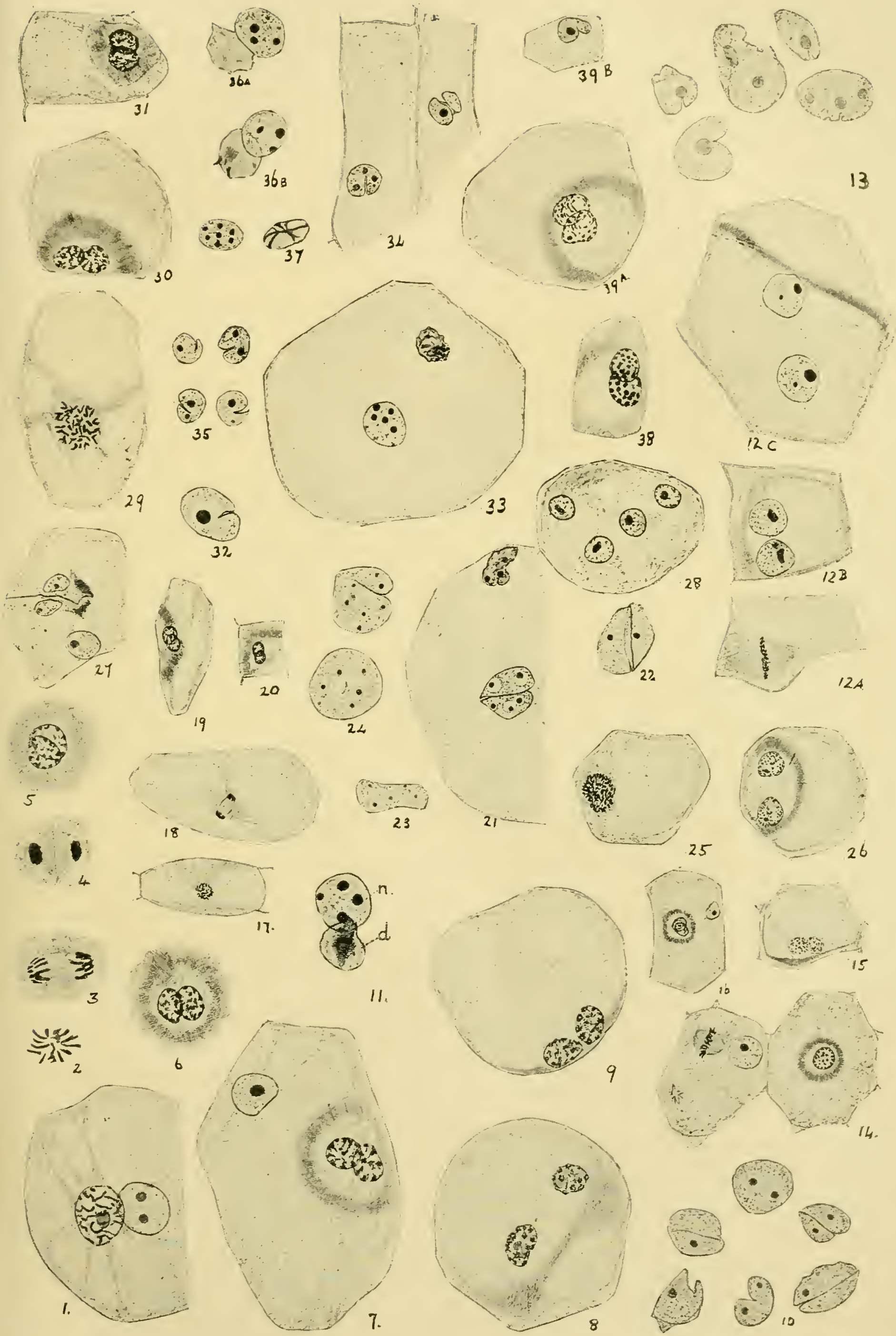
Figs. 14, 15.—*Chrysanthemum Parthenium* Bernh. Pith cells from an axis gathered June 12, 1915.

Fig. 14.—Two adjacent cells, one containing a resting nucleus and a second nucleus dividing at the spindle stage (also a cluster of crystals). The second cell contains a phragmosphere, of which only one of the two nuclei is included in the section.

,, 15.—Another cell, showing a phragmosphere at a later stage, at which it almost coincides with the primordial utricle.

Fig. 16.—*Selaginella Wildenovii* Baker.

Cell of cortex, with a resting nucleus and paired nuclei in a phragmosphere.


31
36A
36B
37
34
39 B
13
39 A
30
29
35
33
38
12 C
32
28
12 B
27
19
20
24
22
12 A
5
18
23
21
25
26
4
17.
n.
d
11.
16
15
3
6
9
2
14.
1.
7.
8
10

To face p. 8.

Figs. 17–20.—*Hippuris vulgaris* L. Axis gathered May 8, 1916.

Fig. 17.—Cortical cell, with nucleus preparing to divide.
,, 18.—Cortical cell, with nuclear spindle, showing chromosomes at the poles.
,, 19.—Cortical cell, with phragmosphere and paired nuclei.
,, 20.—Endodermal cell, with phragmosphere and paired nuclei.

Figs. 21–24.—*Helianthus Nuttallii* Torr. and Gray.

Fig. 21.—One pith cell with two nuclei, one of which is degenerating, at 3 cm. from the apex of a shoot gathered June 9, 1915. (To economize space the outline of the cell is not completed.)
,, 22.—The nucleus of a pith cell between 4 and 5 cm. from the apex.
,, 23.—A nucleus of a pith cell 1 cm. from the apex.
,, 24.—Two nuclei from one pith cell between 5 and 6 cm. from the apex of a young shoot gathered May 23, 1916.

Figs. 25, 26.—*Polygonum cuspidatum* Sieb. and Zucc.

Fig. 25.—Nucleus of a stem parenchyma cell preparing to divide.
,, 26.—Phragmosphere with paired nuclei in a stem parenchyma cell.

Figs. 27, 28.—*Asparagus officinalis* L.

Fig. 27.—Progressive wall formation in ground tissue cell.
,, 28.—Quadrinucleate ground tissue cell.

Figs. 29–32.—*Elodea canadensis* Michx. Gathered June 2, 1916.

Fig. 29.—Cortical cell, with nucleus in process of division, showing chromosomes.
,, 30.—Cortical cell of stem, with phragmosphere.
,, 31.—Epidermal cell of stem, with phragmosphere.
,, 32.—Lobed nucleus from cortical cell.

Figs. 33–37.—*Hemerocallis fulva* L.

Fig. 33.—Cell of ground tissue, with one normal and one degenerating nucleus, from the axis just below a young inflorescence. Gathered May 24, 1916.
,, 34.—Cells of the outer epidermis of the basal part of a leaf gathered January 28, 1916; seen in tangential section, showing the lobed nuclei.
,, 35.—Other lobed nuclei, from the same epidermis as fig. 34.
Figs. 36 A, B.—Pairs of nuclei, in each case one normal and one degenerating, from two adjacent ground tissue cells of the axis just below a young inflorescence, gathered May 24, 1916.
Fig. 37.—Pair of nuclei from one ground tissue cell of the axis just below another young inflorescence, gathered May 21, 1916. As in figs. 36 A and B, one nucleus is normal and the other degenerating.

Fig. 38.—*Alisma Plantago* L.

Cell from the lacunate mesophyll of a young petiole, gathered May 5, 1916, showing a phragmosphere with paired nuclei.

Figs. 39 A, B.—*Monstera deliciosa* Liebm.

Fig. 39 A.—Cell of inner cortex of aerial root, gathered October 20, 1916, showing phragmosphere and paired nuclei.
,, 39 B.—Lobed nuclei from conjunctive tissue of stele of aerial root, gathered November 26, 1915; 4 to 5 mms. from root apex.

transverse sections through the apices of two young shoots. In one case phragmospheres and paired nuclei were first seen at about 0·20 mm. from the apex. At this level the section, which was irregular in outline owing to the leaf rudiments, was only 0·22 to 0·26 mm. in diameter. In the second case the result obtained was of a similar order, a phragmosphere being observed in the epidermis at 0·24 mm. from the apex.

The ground tissue of the "head" is, as we have already shown, characteristically binucleate, but further down the axis we come to a region in which most of the cells are uninucleate. The transition is gradual and cannot be said to occur at any fixed level, but, in a shoot gathered early in May, 3 to 4 cm. from the apex is a good place to look for it. Phragmospheres have, however, been observed at nearly 6 cm. from the apex, and the binucleate character is very persistent in the case of individual cells, notably certain small, deeply staining elements in the pith which probably contain mucilage. At about 2·5 to 4·5 cm. from the apex, the nuclei, which are mostly single in the cells, begin to become lobed and irregular in outline (Pl. I, fig. 13); further from the apex the lobing becomes more marked, and the nuclei become flattened and tend to lie close to the walls. In a shoot about 19 cm. long which was examined, single nuclei, more or less irregular in outline, were found to persist to the base.

The question of how the transition from two nuclei to one takes place is extremely difficult to answer. As in the case of *Eremurus*, there are many bilobed, single nuclei to be found whose appearance at first glance suggests that fusion has occurred, and sometimes two nuclei are seen lying in a close proximity which favours this idea. In some plants the number of nucleoli might be a guide to whether fusion had taken place, but in *Asparagus* no help is to be looked for in this direction, since the number of nucleoli is liable to much variation. For instance, in the same section four cells were observed, each with a pair of nuclei, containing nucleoli in the following numbers:—1, and 1; 2, and 1; 2, and 2; 3, and 3. I am inclined to think that fusions, if they ever occur, are of entirely subordinate importance in reducing the number of nuclei, the main reason for this opinion being that the bilobed character, which is so conspicuous a feature of some of the older nuclei, seems to arise *gradually*, and at a somewhat later stage than the transition from two nuclei to one. The importance of bilobing is also diminished when we see (as in Pl. I, fig. 13) that it is not universal, some of the nuclei being lobed quite irregularly. If fusion be excluded, another possibility which must be considered is the deferred production of walls between the paired nuclei; but of this our observations have furnished no evidence whatever, and the probabilities seem to be altogether against such an occurrence. The phragmoplast, in the case of binucleate cells, was converted

into a phragmosphere which ultimately became merged in the general cytoplasm, so it is difficult to see what apparatus could be brought into play at a later stage to produce a wall. This leaves us with a third alternative, which appears to have most in its favour. There are indications that, of the pair of nuclei within a single cell, one is apt to become senile more rapidly than the other, and we sometimes see a cell containing one nucleus in fair preservation, while the other is smaller, somewhat dense, and possibly in process of disappearance. But we have been unable, in spite of repeated attempts, to get really critical evidence on this point, and, though the degeneration of one nucleus seems the most probable method by which the transition from two nuclei to one is brought about, we cannot regard it as definitely proved.

Since the above account of *Asparagus officinalis* was written, a recent paper by Schürhoff* on nuclear fusions in the shoot apex of this plant has come to our notice. This author seems to have overlooked the multinucleate condition of the ground tissue in general, but he describes the occurrence of "nuclear fusions" in the cells at the periphery of the vascular bundles, after these have become binucleate. He states that he has not determined the origin of the binucleate condition in the younger stages, but that in older stages it occurs through the breaking down of the partition walls between adjacent cells. I have examined more than a hundred hand and microtome preparations, stained in various ways, made from nine shoots of *Asparagus*, mostly of the age of those used by Schürhoff, gathered in two successive years, and fixed on the spot with chrom-acetic or alcohol acetic, but I have never observed any indication of the breaking down of walls or of nuclear migrations such as he describes. On the contrary, I have seen paired nuclei with phragmospheres in the ground-tissue cells at the periphery of the vascular bundles, which are apparently the elements to which he refers; thus, the origin of the binucleate condition is precisely the same here as in the rest of the ground tissue. The "fusions" which he describes are no doubt the lobed nuclei whose significance we have already fully discussed.

3. *Helianthus Nuttallii* Torr. et Gray (Pl. I, figs. 21–24).

Young axes of the Perennial Sunflower, *Helianthus Nuttallii*, were examined at stages at which the rudimentary inflorescence was just becoming differentiated within the terminal bud. Binucleate cells and phragmospheres were found to make their appearance remarkably near the tip; in the case of one axis, which was cut into serial sections, the first phragmosphere was seen at less than 0·1 mm. from the extreme apex. At this level

* Schürhoff, P. N. (1916).

there was no sign of differentiation of vascular tissue, but the phragmosphere observed occurred in the central region, which would subsequently become the pith. In a series of sections through a second axis, at a slightly more advanced stage than the first, a typical phragmosphere with its paired nuclei was seen at about the same distance from the apex—in this case slightly more than 0·1 mm. In passing down the axis the binucleate cells become rapidly more numerous. In an axis gathered on May 23 it was found that, at 1 cm. from the apex, binucleate cells were extremely common in the pith, and trinucleate cells also occurred, while occasional binucleate cells were seen also in the cortex. At 1·5 cm. from the apex a large proportion of the pith cells had become uninucleate. Binucleate cells, however, could be seen as far from the apex as the ninth centimetre, but they steadily became rarer, and in the tenth centimetre none were detected. Variation in the length of the binucleate phase occurs in different shoots, for in another axis of smaller diameter no binucleate cells could be found even in the sixth centimetre.

The young nuclei of *Helianthus Nuttallii* are rounded, but in the region in which the transition from a binucleate to a uninucleate condition takes place a number of nuclei can be seen whose appearance suggests fusion very strongly (Pl. I, figs. 21 and 22). A form with two well-marked pointed lobes is decidedly characteristic. Such cases as that drawn in Pl. I, fig. 21, appear however to invalidate the fusion interpretation, since a deeply bilobed nucleus may sometimes be found in the same cell as a second nucleus which is either normal or in a state of degeneration. It is conceivable, though unlikely, that such a case might represent the subsequent history of a trinucleate cell in which two nuclei are fusing and one degenerating. But besides symmetrically bilobed nuclei, we also find examples of curiously elongated forms (Pl. I, fig. 23), and of lobing into two highly unequal parts (Pl. I, fig. 24). Such irregularity detracts very much from the probability of the fusion hypothesis, and, as in the other cases here described, it seems that the transition from the binucleate to the uninucleate stage comes about by the degeneration of one nucleus (Pl. I, fig. 21), while lobing is merely a characteristic of the single nuclei in the later stages of their career. But at the same time I feel that in this case my preparations do not absolutely dispose of the possibility that the "degenerating" nuclei may be artefact.

4. *Helianthus tuberosus* L.

Shoots of the Jerusalem Artichoke, *Helianthus tuberosus* L., were examined for comparison with *H. Nuttallii*, and the behaviour of the nuclei was found to be closely similar in the two cases. Binucleate cells begin to occur very near the apex in *H. tuberosus*;

the first phragmosphere seen in serial sections through an apical bud occurred at a level at which the diameter of the axis, excluding the leaf bases, was less than 0·5 mm. This phragmosphere occurred in the rudimentary vascular zone, which was just becoming distinguishable from the pith by the form of the cells and the staining power of the nuclei and cytoplasm. Binucleate cells rapidly become very numerous, and at 1 cm. from the apex the pith contains a large number of binucleate and some trinucleate cells. Binucleate cells occur also, though less frequently, in the cortex. The binucleate phase is somewhat protracted; phragmospheres have been observed at 19 cm. from the apex in a shoot gathered on June 5, while occasional binucleate cells occurred in the outer part of the pith at 80 cm. from the apex in a stem collected on June 20 in a previous season. The change from the binucleate to the uninucleate condition comes about through the degeneration of one nucleus. Cells showing one normal nucleus, while the other is contracted and irregular in form and stains deeply, have been observed at distances of 1, 3, and 5 cm. from the apex. The surviving nuclei are often bilobed, the lobes being sometimes acutely pointed as in *H. Nuttallii.* The number of chromosomes is large, and the number of nucleoli in the resting nuclei may range from 1 to 8, in nuclei observed in the same section.

5. *Syringa vulgaris* L.

In the unbranched, lateral shoot of the common Lilac, *Syringa vulgaris*,* the binucleate phase is well represented. Many of the pith cells are bi- or even tri-nucleate, and binucleate cells occur, though less freely, in the smaller-celled cortex. These lateral shoots grow to a considerable length in a single season, and their interest, from our point of view, lies in the fact that they are characterized by binucleate cells throughout a remarkably long region. In two sets of serial sections through different apical buds, the first phragmosphere was observed in each case at about 0·1 mm. from the apex; while in a shoot gathered on June 19 binucleate cells were still to be found in the perimedullary zone as far as 93 cm. from the apex. The binucleate cells still persist in the perimedullary zone after the inner cells of the pith have become uninucleate or have lost their nuclei altogether. In the older part of the shoot, the pith nuclei show signs of decadence, and there are some rather obscure indications that in the case of cells with paired nuclei one may degenerate more rapidly than the other. But the long continuance of the binucleate phase makes this plant an unfavourable subject for following out the fate of the nuclei.

* Miss Prankerd (1915) has recorded the occurrence of binucleate cells in the petiole of this species.

6. *Monstera deliciosa* Liebm. (Pl. I, figs. 39 A, B).

In the aerial roots of *Monstera deliciosa* certain cells remain binucleate for a very long time. In a root fixed on October 25, 1915, many binucleate cells were seen in the inner region of the cortex at a distance of 1 to 2 mm. from the apex. At a little further from the apex occasional cells with 3, or even 4, nuclei were observed. Phragmospheres (Pl. I, fig. 39 A) were first noticed at about 4 mm. from the apex. In order to see how far back the binucleate cells extended, another root was fixed in May 1916, and it was found in this case that, even at a distance of 38 cm. from the apex, many of the cells of the inner part of the cortex were binucleate. Unfortunately the still older part of this root had not been preserved. Later in the season (in August) an old woody root was obtained; this was incomplete at the apex, but the part that remained was 58 cm. long. It was found that even at the base of this root, at a point which was thus probably considerably more than 58 cm. from the apex, occasional binucleate cells still occurred. At this stage the cortex had become interspersed with thick-walled fibres, and most of the nuclei had disappeared. The nuclei of the surviving binucleate cells had become angular and irregular in form.

In the conjunctive tissue of the young stele the cells are uninucleate, but the nuclei show a tendency to be deeply bilobed (Pl. I, fig. 39 B). This lobing occurs very near the tip of the root; it has been seen at a distance of 4 to 5 mm. from the apex in an apparently well-preserved root, and we do not think it can be dismissed as an indication either of senility or of imperfect fixation. It closely recalls the lobing of the nuclei in the stelar parenchyma of *Stratiotes aloides** roots (see pp. 19–21).

7. *Hemerocallis fulva*, L. (Pl. I, figs. 33–37), *Nothoscordum fragrans* Kunth, and *Alisma Plantago* L. (Pl. I, fig. 38).

In 1880 Strasburger† stated that he had searched unsuccessfully for nuclear "Fragmentation" in plants belonging to seven Monocotyledonous genera which he names. He enters into no further details, but it seems probable that if in his search for amitosis he had met with binucleate cells, he would have mentioned the fact. It was therefore decided to investigate some of the cases to which he refers, in order to see whether they were really exceptional in this respect. Three of his seven cases were chosen at random, *Hemerocallis fulva*, *Nothoscordum fragrans* and *Alisma Plantago*, and it was found that all three showed binucleate cells differing in

* Arber, A. (1914). † Strasburger, E. (1880).

no essential respect from those of the other examples described in the present paper.

In the young flowering axis of *Hemerocallis fulva* binucleate and trinucleate cells are common in the ground tissue, and I have observed prophase and spindle stages and phragmospheres. The chief interest of this plant however is that it furnishes particularly definite evidence as to the fate of the nuclei;* the cells apparently become uninucleate by the degradation and disappearance of one member of the pair. Pairs of nuclei from individual cells, one of which seems to be degenerating while the other remains more or less normal, are shown in Pl. I, figs. 33, 36, and 37.

I have also examined the leaves of *Hemerocallis fulva*, and have observed binucleate cells and phragmospheres in the mesophyll of the basal region of a young leaf. This is the growing region, as I have demonstrated by marking off the leaf with indian ink into zones of 1 cm. and measuring the growth of the zones. The epidermal cells show a peculiarity which may be mentioned here. They are always, so far as I have been able to observe, uninucleate, and in the younger stages the nuclei are rounded, but later on they become very markedly bilobed (Pl. I, figs. 34 and 35). This lobing is obviously not a case of degeneration or senility, as it occurs in very young leaves; I have found it for instance in leaves gathered on January 28, 1916. The nuclei are sometimes so deeply bilobed as to be almost bisected, but we have no evidence that actual division into two ever takes place. The lobing is probably comparable with that observed in the young roots of *Stratiotes*.†

Nothoscordum fragrans shows very numerous binucleate cells in the ground tissue of the young inflorescence axis. One or two phragmospheres with paired nuclei were observed, but the material, which was gathered on April 29, was probably rather too old to show many cells in process of becoming binucleate. The resting nuclei are of a curious irregular form, the significance of which I propose to consider in a later paper.

I have examined a young leaf of *Alisma Plantago* gathered on May 5, 1916. It showed some typical phragmospheres with paired nuclei (Pl. I, fig. 38), and various earlier karyokinetic stages. A young inflorescence axis, also, was collected on June 10. Many cells of the ground tissue were binucleate, but the material was apparently too old to show phragmospheres.

8. *Polygonum cuspidatum* Sieb. et Zucc. (Pl. I, figs. 25 and 26).

The stem of *Polygonum cuspidatum* Sieb. et Zucc. was examined because this appears to be the plant in which, under the

* Beer, R. and Arber, A. (1919), p. 12. † Arber, A. (1914), and see pp. 19-21.

name of "*Polygonum Sieboldii*," multinucleate cells were described by Grant.* I can confirm his statement that the ground tissue is multinucleate. I have found binucleate cells both in the pith, cortex and epidermis of the relatively young internodes; in the pith they are extremely numerous. But my observations on the origin of these nuclei fail to accord with those of this author. He writes, "In this plant I have been enabled to trace the formation of the multinucleate condition distinctly, and have found it in all cases to be due to 'direct division.'" I have observed lobed nuclei similar to those figured by Grant, especially at some little distance from the stem apex, but I regard these as senile phases, or possibly in some cases the results of poor fixation, rather than stages of direct nuclear division. In both pith, cortex and epidermis, especially in the younger internodes, the formation of paired nuclei with associated phragmospheres (Pl. I, fig. 26) has been observed. Various karyokinetic stages showing the spindle and chromosomes have also been noticed (e.g. the prophase seen in Pl. I, fig. 25), and there thus seems no reason to doubt that the binucleate condition originates, as in the other cases studied by Mr. Beer and the present writer, by karyokinesis rather than by the amitosis described by Grant.

I can confirm Grant's account of the fusiform and sometimes extremely elongated nuclei which occur in the elongated vascular elements. But I have been unable to detect any cases of the multinucleate cells described by this author as occurring in tangential sections of the vascular bundles. It seems possible that Grant mistook the nuclei of adjacent elements, of very narrow lumen, for nuclei occurring within the same cell—a mistake which it is exceedingly easy to make in the case of these longitudinal sections.

9. *Morus nigra* L. (Pl. I, figs. 12 A–C).

Morus nigra, the Mulberry, is one of the species in which Miss Prankerd † has described and figured the occurrence of multinucleate cells in the pith and cortex of the axis. She considers it probable that the presence of more than one nucleus in these cells is due to amitosis. I have re-examined this plant, and am able to confirm the existence of multinucleate cells in the developing axis. I have found definite evidence, however, that the increase in the number of nuclei comes about, as in other cases described in the present paper, by karyokinesis. Young shoots of Mulberry were fixed on May 8, 1916, soon after the buds had expanded; these were thus probably at a closely similar stage to the material described by Miss Prankerd, which was gathered on May 9, 1915. In both pith and cortex of the young axis spindle

* Grant, A. E. (1886).

† Prankerd, T. L. (1915).

stages were found (Pl. I, fig. 12 A), and also paired daughter nuclei, in telophase and in resting stages, enclosed in phragmospheres (Plate I, figs. 12 B and 12 C). The nuclei, as Miss Prankerd has already recorded, often exceed two in number; I have seen a case of a nucleus dividing by mitosis in a cell also including two resting nuclei. I have not seen in my preparations any group or "complex" of nuclei suggesting an origin from one parent nucleus by direct division, such as that figured by Miss Prankerd (l.c. fig. 5), though nuclei were often seen in close contact, and more or less overlapping one another. It is possible that the appearance of a "complex" may be brought about by the method of fixation used. The nuclei of *Morus* have one or more nucleoli, each surrounded by an exceptionally wide clear areola. This type of structure suggests fragility, and these nuclei seem in practice particularly sensitive to the action of the fixing agent. I have found that when fixed with alcohol-acetic the nuclei are perfectly distinct, but chrom-acetic acid, which evidently does not suit the material, gives curious results; the individuality of the nuclei in a cell is often obscured, and irregular figures are obtained which might easily be mistaken for amitosis, if the comparison with alcohol-acetic material did not prove them to be artefact. In well-preserved material I have often seen individual nuclei of bilobed form, such as those figured by Miss Prankerd (l.c. fig. 4 B), but I have found no evidence for regarding them as stages in direct division. A somewhat similar lobing of the nuclei observed in the young roots of *Stratiotes*,* which in a former paper I described as an indication of amitosis, I now interpret differently (see pp. 19–21). I have also observed the constant occurrence of neatly bilobed nuclei in the young epidermis of *Hemerocallis fulva*, but here again the lobing appears to have no connexion with direct division (see p. 15).

Miss Prankerd suggests that at later stages the transition to a uninucleate condition is probably brought about by the ultimate occurrence of deferred wall formation between the nuclei of the binucleate cells. I have in my preparations observed nothing which suggests such an occurrence, and on general grounds I am inclined to regard it as unlikely.† On comparing the basal region of an opening bud gathered on May 8 with that of a long shoot gathered on September 3, it was found that the total diameter had increased by 80 p.c., while the number of elements on the greatest diameter of the pith had increased only by about 12 p.c. This shows that the increase in girth during the season's growth is accompanied by relatively little cell division. I have further observed that the mitosis of the pith nuclei is not always followed

* Arber, A. (1914).

† The occurrence of wall formation after amitosis was suggested as a possibility in my former paper on *Stratiotes* (Arber, A. (1914)), but further work has convinced me that this idea is untenable.

by the formation of a phragmosphere; cases of progressive wall formation have also been noticed sufficiently frequently to account for the small amount of cell division that occurs in the later stages of development of the pith. These facts taken together seem to eliminate the possibility of subsequent wall formation occurring between the nuclei of binucleate cells—unless these walls are entirely confined to horizontal planes and are thus invisible in transverse sections.

Morus nigra does not seem to be a particularly favourable plant for studying the fate of the nuclei. My observations lead me to believe that in many cells of the pith the binucleate condition is very persistent, and that both nuclei perhaps survive in some of the cells, as long as these elements remain nucleated at all. In certain cells, on the other hand, I have observed, in September, appearances indicating that one nucleus becomes moribund while the other remains normal. I am thus disposed to think that the transition from the binucleate to the uninucleate condition comes about in the same way as in the other plants here described, but I do not wish to lay much stress upon this point, as my results in the case of *Morus nigra*, if taken alone, are by no means conclusive.

10. *Hippuris vulgaris* L. (Pl. I, figs. 17–20), and *Elodea canadensis* Michx. (Pl. I, figs. 29–32).

In a paper published in 1914 Dr. McLean* has described amitosis giving rise to binucleate cells in the parenchyma of the young stem cortex of species belonging to nine different genera of flowering plants and one fern. Since the observations made by Mr. Beer and the present writer on a number of other genera have, as we have already shown, indicated that the general origin of the binucleate condition is through karyokinesis, I have re-examined two of Dr. McLean's cases. As *Hippuris vulgaris* is the species to which he devotes the greatest attention, and in which he figures the binucleate cells, I chose this plant as a Dicotyledon, and *Elodea canadensis* as a Monocotyledon, for investigation.

In my material of *Hippuris vulgaris* the cortex showed numerous cases of paired fusiform nuclei as figured by Dr. McLean. But I have found no evidence at all that these nuclei arise through direct division, and I have seen none of the stages of "longitudinal fission" which he describes. But on the other hand I have seen all stages of karyokinesis (e.g. Pl. I, figs. 17 and 18), and, finally, phragmospheres with the paired nuclei at rest (Pl. I, figs. 19 and 20). The nuclei are exceptionally small, as will be recognized on comparing Pl. I, figs. 17–20, which represent them, with those, for

* McLean, R. C. (1914).

instance, of *Eremurus himalaicus* (e.g. Pl. I, fig. 1), which are magnified to the same degree. This fact, and a certain difficulty which is experienced in staining the nuclei satisfactorily, probably accounts for the karyokinetic stages and phragmospheres having been overlooked by Dr. McLean, who says, "Amitosis is the only form of nuclear division which has been recognized in the tissues investigated, and from its exceeding frequency in the constituent cells it may be inferred that it is the only form occurring there." In all Dr. McLean's figures the process of nuclear division is already completed; the fact that the pairs of nuclei lie close together does not supply, as far as my experience goes, any evidence for amitosis, since I have often observed the approximation of the paired nuclei in cases in which their karyokinetic origin has been proved.

Elodea canadensis presents no essential differences from *Hippuris vulgaris*. In the region towards the apex of an axis fixed on June 2, 1916, binucleate cells were numerous, especially just above the nodes. Many nuclei were observed in mitosis (Pl. I, fig. 29), and phragmospheres occurred both in the cortex and the epidermis (Pl. I, figs. 30 and 31). There appears to be no evidence of amitosis, but I have seen some lobed nuclei (Pl. I, fig. 32) which might at first sight suggest that direct division was in progress. However from analogy with *Asparagus* and *Eremurus*, in which I have been able to follow their history more closely, I think that these lobed nuclei are probably merely senile.

11. *Stratiotes aloides* L. (Text-figs 1, 2).

In a note published some years ago* I gave an account of certain cytological peculiarities observed in the roots of *Stratiotes aloides*, the Water Soldier. Further work on this subject, in the light of the results obtained in other connexions, has greatly modified the conclusions there expressed. The principal feature to which attention was drawn was the constant occurrence of bilobed nuclei in the tissues of the young roots, especially in the vascular cylinder. Examination of further material has confirmed the view that this lobing is natural and not artefact. Examples are shown in text-figs. 1 and 2. A certain number of binucleate cells were also observed—chiefly in the cortex—and it was supposed that amitosis took place and that the paired nuclei arose through the bilobed nuclei becoming nipped in two. But a further search through material collected in two later seasons has shown that binucleate cells arise in the root cortex of *Stratiotes*, just as in other cases described in the present paper, by karyokinesis associated with a phragmosphere. Owing to the small size of the cells and the

* Arber, A. (1914).

relatively large size of the nuclei, these phragmospheres are somewhat obscure, but at the same time their identity cannot be questioned.*

Paired nuclei and phragmospheres have not only been found near the apex of the roots, but also in the cortex of a young stolon

FIG. 1.—*Stratiotes aloides* L. Lobed nuclei from parenchyma cells of stele of young root. × 535, *circa.*

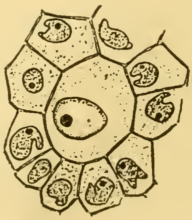


FIG. 2.—*Stratiotes aloides* L. Young vessel surrounded by parenchyma cells with lobed nuclei from transverse section of a young root. × 535, *circa.*

and the mesophyll of a young leaf. Owing to the larger size of the cells, the phragmospheres here attain to a more typical development than in the case of the roots.

Further work has shown that the bilobing of the root nuclei is more widespread than was believed when the previous paper was written; it occurs not only in young roots, but in roots of all ages, being found, for instance, from base to apex in a root 73 cm. long,

* Beer, R. and Arber, A. (1919), Pl. I, fig. 29.

in which it occurred in the stele—in the conjunctive tissue, xylem, parenchyma and companion cells—and also in the cortex. It now seems probable, however, that the bilobing rarely, if ever, goes so far as to give rise to complete division, and thus the roots of *Stratiotes* can no longer be claimed as furnishing examples of amitosis.

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II.—*On Multinucleate Cells: An Historical Study (1879–1919).*

By Rudolf Beer and Agnes Arber.

(*Read February* 18, 1920).

The idea of the cell, as the fundamental unit in the bodies of all organized beings, has now become so deeply ingrained into all our biological thought, that there is a danger of our treating the cell-theory and its associated corollaries rather as rigid axioms than as truths which are still in process of disclosure. It is, after all, only eighty years since the publication of Schwann's epoch-making "Microskopische Untersuchungen," and it may be well to remind ourselves from time to time that the history of the cell-theory has been so brief that our general notions of the construction of the cell and of the relation of its parts must, for many years to come, be open to criticism and revision.

For more than a century and a-half after the first discovery by Robert Hooke of the cellular structure of plants the attention of microscopists was almost exclusively devoted to the cell membrane. It was not until 1833 that Robert Brown observed a nucleus in the cells of a number of plant tissues, his earliest records relating to certain orchids. This discovery marks the first step towards a proper appreciation of the protoplasmic content of the cell as its essential component. The conception of the typical cell as a uninucleate structure is often treated at the present day as if it were a self-evident proposition, the truth of which could be established on *a priori* grounds. It should be remembered, however, that it is really an idea which was arrived at inductively by the earlier cytologists, and which rests entirely on accumulated observations. It was Nägeli, in 1844, who first definitely formulated the now familiar view as to the uninucleate character of the vegetable cell. He concluded, from his extensive researches, that, with the exception of cells in the act of division, pollen grains, pollen tubes and embryo sacs, each element contains only a single nucleus. Further research has modified and elaborated the list of organs that come under the head of Nägeli's exceptions. The literature of botany for the three-quarters of a century which has passed since his work was published includes extensive references to the appearance of the multinucleate character in the structures to which he refers, and also in the pro-embryo of the Gymnosperms, suspensor cells, tapetal tissues, etc. But his central conception of

the uninucleate nature of the typical vegetative cell has remained one of the most firmly established of botanical beliefs. From time to time cases have been brought to light indicating that it is not of universal application, but such cases have until recently been regarded, even by the observers who drew attention to them, as mere exceptions proving the rule, and Nägeli's position has thus remained almost unchallenged. But when we discuss modern developments in the later part of this paper, it will be recognized that in young tissues the occurrence of a binucleate or multinucleate phase is too common to be dismissed as a mere exception, but must be treated as a normal, and possibly almost universal, phase in the life of the plant.

We propose here to give a brief sketch of the work of those observers who, since the time of Nägeli, have recorded the occurrence of more than one nucleus in the vegetative cells of the higher plants. We shall entirely omit from this survey the literature dealing with those recognized exceptions to the uninucleate rule to which Nägeli was the first to refer; these exceptions have chiefly been observed in connexion with reproductive structures, such as endosperms, tapetal cells, etc., and hence have no direct bearing on our notions concerning ordinary vegetative tissues. We shall also omit any account of cases among the Thallophyta, and of pathological examples.

Disregarding certain early references to binucleate cells, which are probably mere errors due to indifferent optical appliances and a rather vague conception of the nucleus, we find that the earliest record of the occurrence of more than one nucleus in the purely vegetative cells of a Phanerogam is due to Schmitz (1879), who observed this phenomenon in the older parenchyma cells of *Glyceria aquatica*, *Taraxacum officinale*, etc. He had examined the Algæ widely from this point of view, and his notes on Angiosperms were merely a side issue, but he prophesied that further work would reveal the presence of multinucleate cells in a larger number of the higher plants. He also placed on record the observation of another worker in the same laboratory (E. Schmidt), that numerous nuclei occurred in the tubular latex cells of *Euphorbia*.

The next year Treub (1880) published independent observations on the same subject. He states that the large cells of the parenchyma of *Cercus multiangularis* were in several cases seen to contain two nuclei, and the same thing was noted in *Tradescantia hypophæa*. In the pith of *Ochrosia coccinea* long cells occur, the walls of which eventually become considerably thickened. In these cells, when young, Treub found constantly as many as five to eight nuclei; after the thickening of the walls was completed the nuclei were no longer distinct.* A comparable multinucleate stage was described many years later in the case of the woody cells of the

* Pigott, E. M. (1915).

ovary wall in one of the Araliaceæ. "The instances," Treub writes, "of cells with two or more nuclei . . . . perhaps deserve some interest as exceptions to a rule hitherto believed general. However, they may very well merely be more or less frequent abnormalities, and hence they cannot serve as the basis for any theoretical deduction." Probably Treub's most important discovery was the constant occurrence of numerous nuclei in the bast cells and laticiferous tubes of a large number of plants. In both types of element the nuclei multiplied by mitotic division. He states that there is a tendency for many, if not all, of the nuclei of one cell to divide simultaneously.

In the same year Johow (1880) described multinucleate cells in the older tissues of several Monocotyledons. He gave most of his attention to the internodal parenchyma cells of *Tradescantia*, in which he believed that the plurality of nuclei arose through amitotic division. Strasburger (1880) confirmed this conclusion, and *Tradescantia* has since remained one of the classic examples of amitotic division, being used as an illustration of this phenomenon in every botanical laboratory. But, as we have shown in a recent paper,* we believe that many (if not all) of the cases of amitotic division in this plant, which have been figured and described, are merely instances of changes of form in the nuclei, not necessarily bearing any relation either to division or fusion.

In several other Monocotyledons Johow obtained similar results. He observed lobed nuclei, which he interpreted as cases of amitosis, in the inner tissues of the leaf of *Allium cepa*, constricted nuclei in the floral axis of *Orchis maculata*, fragmented (zergliederte) nuclei in the scape of *Tulipa sylvestris*, and nuclei in the petioles of *Anthurium sagittatum* which were traversed by a narrow hyaline strip suggesting direct division. All these cases we now regard, however, not as instances of amitosis, but as coming under the same interpretation as that which we have indicated for *Tradescantia*.

In a later paper (1881) Johow added several other instances of the occurrence of multinucleate cells in the older tissues of Monocotyledons. He observed such cells in the inflorescence axis of *Hyacinthus orientalis* and in the older leaves of *Sempervivum Wulfeni*.

At about the same time Strasburger (1880) also contributed some observations upon the same subject. Like Johow he considered that a fragmentation of the nuclei, often leading to a multinucleate condition, was a widespread phenomenon in the older cells of Monocotyledons. In the tissues of Dicotyledons he found nuclear fragmentation to be much rarer. He however figured lobed nuclei in the very old pith cells of *Tropæolum majus* and what is probably a pair of nuclei lying closely approximated

* Beer, R. and Arber, A. (1919).

in *Nicotiana Tabacum.* In discussing these two cases of lobed and fragmented nuclei, he expressly remarks that they only occur "in very old cells shortly before the total disorganisation of the nuclei. Cells with lobed nuclei are therefore distributed between others which have become entirely devoid of a nucleus. Only very rarely does this constriction of a nucleus lead to its complete division. Multinucleate cells are, therefore, only met with very occasionally." Strasburger also observed lobed nuclei in the vessels of *Bryonia dioica* at the time that their membranes are becoming thickened.

In 1886 a paper by A. E. Grant appeared, which has since been almost entirely overlooked,* and with which we shall therefore deal at greater length than if it had received due recognition. In this memoir, which is entitled "The Multinucleated Condition of the Vegetable Cell," the author records the occurrence of more than one nucleus in the cells of the following species:—*Polygonum Sieboldii, Acanthus mollis, Podophyllum peltatum, Eschscholtzia californica, Impatiens noli-me-tangere, Dictamnus fraxinella, Lilium pyrenaicum* and *Polygonatum multiflorum.* He found the plurality of nuclei in the bast cells, the wood cells and the parenchymatous ground tissue of the stem, and, in the case of *Acanthus mollis,* in the parenchyma of the petiole. Grant was unable to detect any evidence for the existence of mitosis, and he concluded that in all these cases the multiplication of the nuclei takes place by direct division; he figures and describes lobed nuclei in support of this view. He took a remarkably broad view of his results, and his paper, which was written thirty-six years ago (having been read three years before it was published), does not deserve the oblivion into which it has fallen.

Before passing on to the more recent work on multinucleate parenchyma cells, we may deal with a series of observations on a multinucleate condition observed in the young vessels of certain plants. In the development of the larger pitted vessels of the Dioscoreaceæ, Pirotta and Buscalioni (1898) observed a multinucleate phase in the vessel initials. The vessels develop from longitudinal series of cells which are at first isodiametric, but which ultimately become elongated by marked intercalary growth. The nuclei of these elements are at first single, but they subsequently divide so that each cell may finally possess more than a hundred nuclei.† The primary and secondary divisions are all mitotic, but afterwards the process does not always proceed normally. Eventually the nuclei, cytoplasm and parts of the

* We were unacquainted with this paper at the time that our preliminary note was published, Beer, R. and Arber, A. (1915).

† Hill, T. G. and Freeman, Mrs. W. G. (1903), give an account of the origin of plurality of nuclei in the root vessels of *Dioscorea prehensilis* which conflicts with that of Pirotta and Buscalioni, but the Italian observers' work is much more widely based, and its accuracy may probably be accepted.

transverse walls are resorbed, and the characteristic sculpturing is formed.

In several species of *Euphorbia* and *Ricinus*, the young plerome elements of the root, destined to form the segments of the vessels, were observed by Smolák (1904) to be quadrinucleate. He found that the plurality of nuclei in the vessel initials arose by mitotic divisions which were not followed by cell divisions or wall-formation. The four nuclei sometimes fused into one long nucleus, e.g. *Euphorbia Lathyris*, but in *Ricinus* fusions were less frequent.

Němec (1910) six years later made a comprehensive study of the multinucleate vessel rudiments and plerome cells of *Ricinus*. He likewise found that the nuclei arose by karyokinesis. A spindle is produced between the nuclei at each division, but this breaks down at an early stage, becomes granular, and soon disappears altogether. From two to sixteen nuclei may be found in a single cell, generally arranged in a longitudinal row. Nuclear fusions may occur, but Němec regards them as rare.

We have now to consider that group of papers on multinucleate parenchymatous cells which includes the most recent work on the subject. Twenty years ago, one of us (Beer, R., 1899) recorded the fact that multinucleate cells of a very pronounced character occur in the stem and leaf-sheaths of a number of Gramineæ. He found this to be the case in *Zea Mays* (stem, leaf-sheath and root), *Secale cereale* (leaf-sheath), *Triticum vulgare* (stem and leaf-sheath), *Hordeum sativum* (leaf-sheath), and *Dactylis glomerata* (leaf-sheath). He called attention to the fact that it is in young, still active tissues that the multinucleate condition is most marked.

In 1914 Dr. R. C. McLean published an account of his observations upon amitosis in the parenchyma of water plants. He found that nuclei which he regarded as having arisen through direct division were frequently to be found associated in pairs in the same cell, while, more rarely, three nuclei might be met with in one cell. Certain stages, which the author regards as representing the actual separation of the two daughter nuclei, were observed. According to McLean's description, no constriction occurs, but the process resembles the longitudinal fission of the Flagellata. His observations relate to eight aquatic species, including both Dicotyledons and Monocotyledons, as well as to two land plants, *Dionæa muscipula* and *Polypodium ireoides*. He believes that cell-division may follow the amitotic division of the nucleus, but he does not describe this in any particular case. We chose two of McLean's cases for re-examination (*Hippuris* and *Elodea*), and although we can confirm his record of multinucleate cells in both plants, we find that the nuclei in question invariably arise by mitosis and not by direct division.*

* Arber, A. (1920).

Simultaneously with McLean's paper one of us (Arber, A., 1914) described multinucleate cells and lobed nuclei in *Stratiotes aloides*. The root-cap of a young adventitious root, and certain cells of the stem cortex through which it was dissolving its way, were observed in some instances to be highly multinucleate, as many as twelve nuclei being observed in one case in a single cell of the root-cap. Lobed nuclei are notably frequent in the conjunctive tissue of the stele. Further work on *Stratiotes* has convinced us that the conclusions expressed in this paper as to the part played by amitosis require revision; we have now observed the origin of the binucleate condition through karyokinesis, and we regard the lobing, which was formerly supposed to be a precursor of amitosis, as having no connexion with any division.*

A year later than the appearance of the two papers which we have just considered, Miss Prankerd (1915) published an account of her researches on multinucleate cells. She recorded the occurrence of elements with more than one nucleus in thirty-six species of plants "widely separated in habit, habitat, and systematic position," including both Vascular Cryptogams and Angiosperms. The plurality of nuclei was observed sometimes in the pith, sometimes in the cortex, and sometimes in both tissues. It was also found in the mesophyll of some plumular leaves (e.g. *Zizania aquatica*) and in the ground tissue of certain Ferns and Monocotyledons. Binucleate cells were usually found, but in certain cases (e.g. *Arum maculatum*, *Limnanthemum peltatum*, *Zizania aquatica* and *Morus nigra*) three or even more nuclei could be observed in some of the cells. It was found that the multinucleate elements tend to occur in regions of activity (cotyledonary nodes of seedlings) and of rapid elongation (axes of buds). Miss Prankerd considers that, in general, the plurality of nuclei arises by amitosis. We have re-examined certain of the species with which Miss Prankerd's studies were concerned, and again—as in the case of Grant's and McLean's work—we find that we can confirm the existence of the multinucleate phase, but that our observations point entirely to mitosis, and not direct division, as the mode of origin of the extra nuclei.†

In the same issue of the Annals of Botany as that in which Miss Prankerd's paper appeared, we published a preliminary note dealing with the same subject (Beer, R. and Arber, A., 1915). We recorded a plurality of nuclei in the young parenchymatous tissues of seventy-six species, chiefly Angiosperms, but including also a Gymnosperm and a Vascular Cryptogam. This phenomenon seemed to us so widespread that we suggested the possibility that a binucleate or multinucleate stage might often intervene as a normal phase of development between the meristematic and adult

* Arber, A. (1920).

† Ibid.

conditions. The main difference between our results and those of the other authors quoted is that, according to our observations, the plurality of nuclei arises, not by amitosis, but by a process of karyokinesis with which certain peculiar features are associated. In 1919 we published a fuller paper * in which we dealt on broad lines with the occurrence of multinucleate cells in vegetative tissues. We recorded the occurrence of more than one nucleus—two being the commonest number—in the young parenchymatous tissues of 177 species representing 60 families, including members of the Filicales, Equisetales, Lycopodiales, Psilotales, Isoetales, Gymnosperms, Monocotyledons and Dicotyledons. Our observations related chiefly to stems, but we also found a binucleate phase in leaves and roots. It is most conspicuously developed in parenchymatous tissues, such as the cortex and pith of the axis, and the mesophyll of the leaf, but we have also seen it in the central cylinder. The "heads" of Asparagus, at the stage at which it is usually cut, form particularly favourable material on which to demonstrate the binucleate phase, which is a striking feature of the ground-tissue cells.

As we have already mentioned, we find that the binucleate condition is invariably brought about by mitosis. The division occurs normally in the earlier stages, up to the period at which the two daughter nuclei are at the poles of the spindle, while the cell-plate is just being initiated. But at this point the mechanism seems to break down and the cell-plate is resorbed, while the phragmoplast,† with its associated cytoplasm, goes through a singular metamorphosis. It becomes vacuolate in the centre and develops into a hollow sphere which gradually grows until it encloses both the daughter nuclei, and then, by its further extension, ultimately merges into the cytoplasm lining the cell wall. For this hollow shell we have proposed the term "phragmosphere." In some cases it is exceedingly well-defined and stains deeply, giving the sections in which it occurs a curious appearance of exhibiting cells within cells.

The binucleate condition of parenchymatous cells persists in some cases for a very long time—possibly throughout the life of the element—but in other cases the cells eventually become uninucleate. This seems to be brought about by the degradation and resorption of one nucleus of the pair. We have seen no evidence of any other method of transition from the binucleate to the uninucleate state—such, for instance, as fusion of the nuclei, or a belated development of walls between them. In old tissues, lobed nuclei are frequently seen which might easily be taken to be stages either

* Beer, R. and Arber, A. (1919); see also Arber, A. (1920).

† This convenient term was introduced by Errera, L. (1888), to denote the complex of spindle fibres which generally assumes the form of a "Rotationsellipsoid."

in fusion or amitosis, but we have come to the conclusion that these are merely degeneration stages.

We must not here enter upon the far-reaching question of the significance of the binucleate phase. It may possibly have its value in increasing the area of nuclear surface in contact with the cytoplasm; we have shown elsewhere* that there is a certain amount of evidence in favour of this view. But on the other hand the binucleate condition may merely indicate that the cytoplasm flags in its capacity for active division before the nucleus shows any sign of having passed from the energy of youth to the repose of age.

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SUMMARY OF CURRENT RESEARCHES

RELATING TO

ZOOLOGY AND BOTANY

(PRINCIPALLY INVERTEBRATA AND CRYPTOGAMIA),

MICROSCOPY, ETC.*

ZOOLOGY.

VERTEBRATA.

a. Embryology, Evolution, Heredity, Reproduction, and Allied Subjects.

Relation of Spermatozoa to Certain Electrolytes.—J. GRAY (*Proc. Roy. Soc.*, 1920, **91**, 147–57). A suspension of the spermatozoa of *Echinus miliaris* in sea-water behaves towards trivalent positive ions in exactly the same way as a suspension of negatively charged particles of such colloids as albumen or globulin. It is only in those solutions which are capable of maintaining the normal negative charge that movement of spermatozoa can take place. Trivalent ions flocculate sperm suspensions by removing the negative charge. The action of the hydrogen ions is very intense, and changes the surface charge from negative to positive without any immediate flocculation. The experimental evidence goes to show that the surface charge on the spermatozoa is of fundamental importance to their activity, and that this charge depends upon the nature of the solutions with which the spermatozoa are in contact. Just as particles of different colloids (or membranes of different composition) possess different charges when in contact with the same solution, so the eggs and spermatozoa of different species may have different surface charges when in sea-water of the same composition. If, therefore, the possibility of fertilization of the egg depends partly on the mutual relationship between the surface charge of the egg and that of the spermatozoon, it is possible that many cases of artificial hybridization may find a simple solution. It is proposed to investigate the surface charges of the spermatozoa of different species, with a view to determining whether the possession of a critical surface charge controls the fertilizing power of the sperm for eggs of the same and of different species. J. A. T.

* The Society does not hold itself responsible for the views of the authors of the papers abstracted. The object of this part of the Journal is to present a summary of the papers *as actually published*, and to describe and illustrate Instruments, Apparatus, etc., which are either new or have not been previously described in this country.

Testicular Grafts.—Ed. Retterer (*C. R. Soc. Biol.*, 1919, **82**, 1022–5). Testicular grafts have been previously made in amphibians and birds, and it has been noted that the seminiferous tubules continue for some time to form spermatozoa, but that the epithelium gradually degenerates. Mammalian testes transplanted into the peritoneal cavity or underneath the skin show after some time only Sertoli's cells, which multiply by mitosis, or are converted into giant-cells or indifferent epithelium. Testes of rats grafted on the internal surface of the abdominal wall showed degeneration of seminal cells; the seminiferous tubules became covered only by a succulent epithelium, and the interstitial cells increased in number. Retterer has made grafts of testes or pieces of testes in the goat. Both in the entire testes and in the pieces the only parts that survived were the superficial portions which continued to receive nutritive plasma. The superficial cells that survived changed their structure and mode of development. A few continued to divide to form small nuclei and the heads of spermatozoa. The great majority were transformed into a mass of coalescent cytoplasm which ended by becoming reticular connective tissue. J. A. T.

Experimental Degeneration of Testis in Dog.—Albert Kuntz (*Anat. Record*, 1919, **17**, 221–34, 4 figs.). Elimination of the sympathetic nerve supply to the testes is followed by degeneration of the seminal epithelium and accompanying hypertrophy of the interstitial secretory tissue. The same degeneration followed in both testes after ligature and resection of the right ductus deferens. The degeneration was similar to that following exposure of the testis to X-rays, or following a diet deficient in the water-soluble vitamines. J. A. T.

Innervation of Gonads in Dog.—Albert Kuntz (*Anat. Record*, 1919, **17**, 203–19, 4 figs.). The sympathetic nerves to ovaries and testes pass distally along the ovarian and spermatic arteries respectively, and enter the organs in more or less intimate association with the blood-vessels or the efferent ducts. The majority of these fibres are derived directly from the sympathetic ramus ascending from the inferior mesenteric ganglia to the renal plexus. The blood-vessels and all other structures in the gonads which contain smooth muscle receive an abundant sympathetic nerve supply. The evidence available does not indicate a sympathetic nerve supply either to the ovarian follicles and the interstitial secretory tissue in the ovary, or to the seminal epithelium and the interstitial secretory tissue in the testis. J. A. T.

Sterility of Mules.—W. M. Goldsmith (*Amer. Journ. Veterinary Medicine*, 1917, *June*, 1–8, 19 figs.). The mule possesses the necessary reproductive organs and the sex impulse. The early cells of the testis show normal cells with fifty ordinary chromosomes and one sex-determiner. The horse has only thirty-six plus the extra chromosome. It is supposed that the ass has about sixty-five chromosomes. According to Wodsedalek, most of the mule's spermatocytes disintegrate during the maturation division, perhaps because of the marked difference in

the numbers of the chromosomes in the two parents. Wodsedalek denies that fertility ever occurs in mules, but Goldsmith cites Lloyd-Jones to the effect that female mules and "hinnies" may be the mothers of colts. Goldsmith has been "unable to find any record, either authentic or otherwise, of a reproducing male mule." There seems to be a lack of *facts* in this and other discussions of the sterility of mules.

J. A. T.

Germ-plasm of Ostrich.—J. E. DUERDEN (*American Naturalist*, 1919, **51**, 312–37). "Without any hesitancy it can be affirmed that in the course of the fifty years during which the ostrich has been domesticated, it has never produced a feather variation, germinal in its origin, such as could be regarded as of the nature of a sport or mutation." The germ-plasm is often very conservative. "The greatest mixture of germ-plasm is going on, but no single hereditary factor or determiner is altered in the process, and has not altered throughout the history of ostrich breeding; only new combinations are formed of factors already available." Crossing does not originate novelties. Artificial selection does not in the case of ostriches do more than sift out the possessors of certain characters and bring them together so as to effect a desired combination in the progeny. The germ-plasm changes as between the northern and the southern ostrich have resulted entirely from internal physiological causes. In many respects the degeneration phenomena in the ostrich appear to be best understood on the conception of autonomous changes and variations in potency of the germ factors. It is possible that by inbreeding an inherent tendency towards reduction (e.g. towards the loss of toe-scales) may be accentuated. J. A. T.

Asymmetrical Duplicity in Chick.—NOEL TAYLOR (*Proc. Zool. Soc.*, 1919, 83–109, 3 pls., 2 figs.). Description of a blastoderm showing asymmetrical duplicity, unique in the respect that both of the embryonal formations exhibited gross structural defects. It seems explicable only on the monozygotic theory of origin, i.e. that both centres originated through some kind of disturbance from a single and possibly normal germ. The primary modification induced in the larger embryonic formation resulted in the inhibition of the normal growth of the anterior portion of the nervous system and of the formation of the head-fold. From this there followed various secondary modifications. Although no true head-fold could have been present, there was nevertheless a well-developed fore-gut. While it has been experimentally demonstrated that the material of the primitive streak does not enter into the formation of the brain, it appears from the case in question that the material from which the anterior region of the medullary plate normally arises may under certain circumstances have the power of giving rise to a primitive streak-like mass of tissue. The importance of the case is that the two embryonal formations were from the first unlike, the asymmetry being intimately bound up with the actual origin of the two centres of embryonal formation from a single centre, and not resulting from secondary modification in the course of development.

J. A. T.

Duplicity in Chick Embryos.—G. W. TANNREUTHER (*Anat. Record*, 1919, **16**, 355–67, 6 figs.). A description of some unusual forms of partial and complete duplicity in chick embryos, where the blastoderm divides into several equipotent regions. In one case the blastoderm showed four primitive streaks; in another the embryo anterior to the primitive streak showed an almost complete duplication of parts; in a third case there is an almost complete duplication of structures on a common blastoderm; in another there seem to have been two independent primitive streaks with the anterior ends of the head processes continuous or in immediate contact. J. A. T.

Absence of Hind Legs below Femur in a Full-term Pig.—M. CARREON (*Philippine Journ. Sci.*, 1919, **14**, 201–5, 1 pl.). In an otherwise normal litter one member had no hind limbs below the femur, and had also cleft palate. It is reasonable to assume that the two abnormal conditions had the same underlying cause. Both show an interrupted growth very early in the development of the pig. Everything points to some physico-chemical interference with growth.

J. A. T.

Development of Membrane Bone.—ED. RETTERER (*C. R. Soc. Biol.*, 1920, **83**, 4–6). The development of the first bony trabeculæ in a connective membrane has been studied in the case of the human maxilla. In the mesodermic tissue in which the bone develops there are cells with a granular and reticular framework containing only hyaloplasm. This becomes dense and eosinophilous. The reticulate and anastomosing filaments become more numerous. Thus arises the first intercellular or osseous substance. Between it and the nucleus a clear cytoplasm appears, which forms the cellular body of the bone-cells. These are separated from the intercellular substance by the formation of a capsule. The inter-cellular or osseous substance increases and differentiates into a framework and an amorphous calcified mass.

J. A. T.

Developing Connective Tissue.—RAPHAEL ISAACS (*Anat. Record*, 1919, **17**, 243–70, 6 figs.). A study of developing connective tissue in embryos of chick, pig, and man, and of colloids of gelatin, egg albumin, and fibrin under controlled laboratory conditions. The intercellular jelly of embryonic and adult tissue is structurally homogeneous and contains no network of fibrils. The so-called fibrils of connective tissue and neuroglia are fixation artefacts. The fibres of adult tissues are formed by the thickening (concentration increase) of the colloid lying between the fibroblasts. The polarization of the cells, their movement, and the stress exerted on the growing tissue, all serve to give the adult white fibres their arrangement as strands in a bundle. J. A. T.

Embryological Studies of Indian Fishes.—T. SOUTHWELL and B. PRASHAD (*Records Indian Museum*, 1919, **16**, 215–40, 4 pls.). 1. A description is given of two Leptocephalids from the brackish waters of the Gangetic Delta. 2. An account is given of the life-history of

Notopterus chitala, a teleost of the Ganges. The glutinous eggs are usually laid on solid bodies, such as stones; the male emits milt over them; they are jealously guarded; seven stages of development are described. 3. The egg-case of *Chiloscyllium griseum* is described. It has attached to one of the longer sides a very long (134 mm.) and thick mooring cord of a silky (?) material, which would be useful in anchoring the egg-case to any object on the floor of the sea. 4. Intra-uterine embryos are described in a number of Indian Elasmobranchs. In the earlier embryonic stages of the *placental* forms there is no placenta, but the yolk-sac functions as such. Later on a placenta develops by a modification of the yolk-sac, and nourishment is obtained directly from the blood of the mother. In some cases additional structures or appendicula are developed on the placental cord, and these probably absorb the uterine secretion in which the embryo is floating. In the *aplacental* forms the yolk-sac persists as such through the greater part of the embryonic life, and the yolk is directly taken into the gut with or without the intermediation of an internal yolk-sac. Possibly the branchial filaments help in absorption, and in earlier stages they absorb uterine secretion. The blood-vessels in the mesoblastic portion of the yolk-sac are also absorptive. In later stages special processes of the maternal uterine wall (trophonemata) enter the embryonic spiracles and pour in secretion. The stomach does not function as such during the embryonic period, but is a mere channel to the absorptive colon.

J. A. T.

Muscular Metamerism.—HENRI V. VALLOIS (*C.R. Soc. Biol.*, 1920, **83**, 111–3). In most fishes and Urodela the myosepta which persist in the adult have undergone foldings which completely modify their insertion. The episomatic portion of each myotome does not correspond to one intervertebral space as in the embryo, but extends over adjacent spaces in front and behind. It is not accurate to say that the primitive metameric structure persists in the adult; the muscular metamerism does not correspond with the skeletal metamerism. The author discusses the state of affairs in higher vertebrates where there is a general disappearance of the myosepta. J. A. T.

Neuromeres and Metameres.—H. V. NEAL (*Journ. Morphol.*, 1919, **31**, 293–315, 17 figs.). However doubtful the interpretation of the so-called neuromeres of vertebrate embryos in other regions of the body, the hind-brain neuromeres or rhombomeres can be explained neither as primordia of adult organs nor as the passive results of mechanical pressure produced by the bending of the neural tube. A phylogenetic interpretation of them therefore appears to be not impossible. Neuromerism is not seen in the central nervous system of Amphioxus. It is more conspicuous in the embryos of higher Chordates than in those of lower, and it is more conspicuous in the head than in the trunk. Analogous evidence led to the abandonment of the vertebral theory of the skull. The author suggests that the rhombomeres may have arisen in adaptation to the branchiomeric segmentation; their neuromuscular relations are hard to reconcile with the assumption of metameric value.

The mesodermic somites afford reliable criteria of the primitive metamerism of the head, but the same cannot be said of the rhombomeres. The chief evidence of the metameric value of neuromeres consists in their numerical correspondence with the mesodermic somites, but this correspondence obtains in the head region of vertebrates for only the primary brain vesicles (Neal's neuromeres I–VII), and not for the secondary subdivisions of these, such as rhombomeres 1 and 2, which result from the secondary subdivisions of neuromere III. Except in the case of neuromeres II and III (Neal), the motor nerve relations of the neuromeres do not accord with the supposition that they are metameric structures. J. A. T.

b. Histology.

Cytology.—L. Doncaster (*An Introduction to the Study of Cytology, Cambridge University Press*, 1920, xiv + 280 pp, 24 pls., 31 figs.). An admirably clear and scholarly introduction to cytology which will be widely welcomed. It is marked by careful workmanship and sound judgment. The illustrations are admirable and abundant, and there is a representative bibliography. The subjects dealt with are the following: The cell in general and protoplasm, the cell-organs, cell-division, the centrosomes, the maturation of the germ-cells, fertilization, segmentation, natural and artificial parthenogenesis, the cytological basis of sex-determination, germ-cell determinants, the theory of the individuality of the chromosomes, the mechanism of hereditary transmission, the rôle of the cytoplasm in development and heredity. As was to be expected from the author's personal investigations, prominence is given to the cytological basis of hereditary transmission and of sex-determination; but to these questions a great part of the cytological research of the past fifteen years has been devoted, and a judicial up-to-date exposition is very timely. The book hardly deals with the physiological and biochemical sides of cytology, and we venture to express the hope that this self-denying ordinance will not be adhered to in subsequent editions. J. A. T.

Chromosome Dimensions.—C. F. U. Meek (*Proc. Roy. Soc.*, 1920, **91**, 157–65, 2 pls.). Measurements of a large number of chromosomes in different types lead to the following conclusions:—The degree of somatic complexity of an animal cannot be correlated with the lengths of the chromosomes composing its complex, nor with the diameters of these, nor with the total volume of these, nor with their number. There are many different chromosomes in different types, and the chromosomes composing the spermatogonial complex are not necessarily identical in diameter with those composing its secondary spermatocyte complex. All chromosomes composing an individual complex are not necessarily of the same diameter. The tendency noted in a previous communication for the chromatin volume and chromosome diameter to increase from simple to complex animals must have been fortuitous.

J. A. T.

Specific Substances in Leucocytes of Immunized Animals.—ALOIS BACHMANN (*C. R. Soc. Biol.*, 1919, **82**, 1031–3). A study of the leucocytes of guinea-pigs immunized against Eberth's bacilli reveals the presence of specific substances which can be isolated. To these substances the leucocytes owe their specific immunizing power. The substances are more stable products than the endolysins. Indeed, they were experimentally isolated by the destruction of the endolysins by a method which left the specific substances intact. J. A. T.

"Fatty Cells" of Pulmonary Alveolus.—E. FAURÉ-FREMIET (*C. R. Soc. Biol.*, 1920, **83**, 11–13). In the pulmonary alveolus of ox, cat, rat, and other forms "fatty cells" have been described. The delicate conjunctivo-vascular support of the wall of the alveolus is covered on each surface with an epithelium of non-nucleated flat cells and of nucleated globular cells. The nucleated globular cells contain lipoid globules, which appear to be in great part due to cholesterin. As the result of slight irritation these elements multiply and may become mobile phagocytes. If they become free they lose the lipoid inclusions
J. A. T.

Blood Corpuscles of Camelidæ.—J. JOLLY (*C. R. Soc. Biol.*, 1920, **83**, 125–7). The blood of a Llama showed regularly oval red blood corpuscles, 8 μ by 4 μ, without trace of nucleus. Seen in profile they looked like spindles. They are delicate lamellæ, but when they float they show a marked tendency to roll themselves up on their longitudinal axis. J. A. T.

Haversian Systems in Membrane Bone.—LESLIE B. AREY (*Anat. Record*, 1919, **17**, 59–61, 2 figs.). Sections from bones like the parietal and temporal controvert current statements as to the absence of Haversian systems in membrane bone. These erroneous statements have helped to perpetuate a false histological distinction between bones primarily of intracartilaginous and bones primarily of intramembranous origin. The fact is that in the arrangement of bone tissue into periosteal, Haversian, and interstitial lamellæ there is essential architectural uniformity, irrespective of the mode of development.
J. A. T.

Minute Structure of the Brain.—G. FUSE (*Arb. Anat. Inst. K. Japan Univ. Sendai*, 1919, **2**, 1–384, 218 figs.). A series of researches on the minute structure of various parts of the brain in man and mammals. They deal, for instance, with the medulla oblongata, the trigeminal root, the corpus trapezoides, the zona quinto-olivaris superior, and the auditory tracts. J. A. T.

Lateral Line of Polyodon spathula.—HOMER B. LATIMER (*Trans. Amer. Micr. Soc.*, 1919, **38**, 189–206, 2 pls.). As the lateral canal passes backwards from the gill region its diameter gradually becomes

smaller. The sensory ridges are located on crests or portions of the canal approaching the surface. The lumen of the canal here is always larger than just anterior or posterior to the ridge. The longest ridges are in the anterior region. There is a gradual diminution in length in a posterior direction until just before the tail is reached. Upon the tail itself a slight increase in length occurs. No branchlet, except on the caudal fin, where there seems to be great irregularity, is given off without a sensory ridge at its posterior end. Ridges may or may not occur between the branchlets. Though there is a slight grouping, branchlets are given off throughout the entire length of the lateral canal. J. A. T.

Investigations on the Spiroptera Cancer, III.–VI.—JOHANNES FIBIGER (*Det. Kgl. Danske Videnskabernes Selskab. Biologiske Meddelelser*, 1918–19, **1**, 9, 10, 11, 14). Following on his previous observations on the development of carcinoma in 12 black and white laboratory rats infected with a round worm, *Spiroptera neoplastica*, Johannes Fibiger records further similar experiments on 214 black and white laboratory rats. Of these, 102 rats survived more than 45 days, of whom 54 (53 p.c.) developed carcinoma of the fundus of the stomach. His ability to produce carcinoma at will is a big step forward in the investigation of the origin of tumour cells from normal tissue, as transplantion experiments only permit of the study of the continued propagation of fully-developed spontaneous tumours. The experiments consisted of feeding the animals with the muscles of cockroaches (*Periplaneta americana* and *P. orientalis*) infected with the larvæ of *Spiroptera neoplastica*. The cockroaches were fed on the excrement of rats containing the eggs of the parasite. The nematode lives attached to the pavement epithelium of the mouth and fundus of the stomach.

Out of 116 rats, in 107 the fundus was examined in serial section. This was necessary in that the growth may be too slight to be seen microscopically, as rats surviving $1\frac{1}{2}$ to 3 months after infection showed carcinomata of only 1 mm. in extent, but in those living up to 6 months the growth reached 2·5 to 5 mm. The earliest development of carcinoma was 45 to 50 days after infection with the larvæ.

Carcinoma was only diagnosed on :—1. The heterotopical down-growth of epithelial cells belonging not only to the normal type of the basal epithelial layers, but mixed up with atypical and keratinized cells partly arranged as spherical masses and horny globes. 2. Infiltration of these cells into the deeper layers splitting up invasively the connective tissue of the mucosa and muscle cells of muscularis mucosæ, forming islets and spurs in the latter or penetrating through this layer into the submucosa. Metastases occurred in 8 cases, and contained no worms or ova. Also carcinomatous growth continued after all the *Spiroptera* had disappeared from the stomach. Whereas previously, as he points out, there have been only 10 (about) recorded cases of cancer of the tongue in domestic animals and none in rats, he has succeeded in the production in rats of 6 cases, 5 by *Spiroptera* infection and 1 by feeding with oats. One hundred and fifteen tongues were examined in serial section (at 10 μ every 10th to 6th or more of which were examined), comprising

in some cases the tongue *in toto*. The growths were typical of cancer of the tongue, showing invasion of the muscles. No metastases were found.

In addition, out of 59 white mice which survived the infection for 45

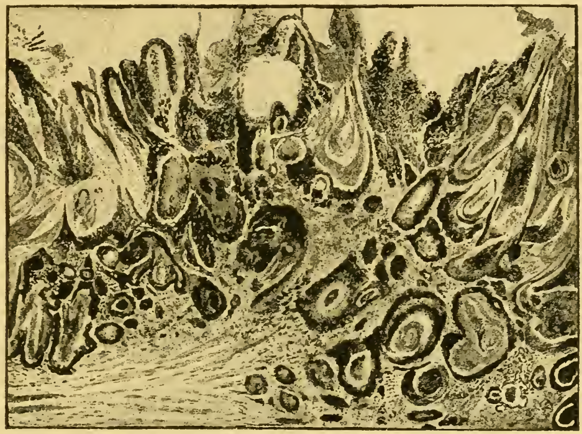


FIG. 1.—*Spiroptera* carcinoma of the tongue in rats.

days or more, 3 developed carcinoma of the fundus of the stomach; but whereas in the rats none showed invasion of the muscularis of the stomach, in the mice 2 showed invasion of all the layers of the stomach wall. This he explains as being due to the early death of the rats

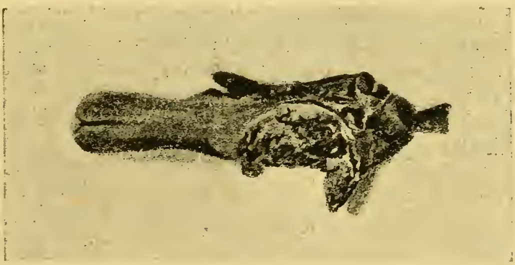


FIG. 2.—*Spiroptera* carcinoma of the tongue of a rat.

(9 to 10 months after infection in longest-lived) compared with the later deaths of the mice (16 and 13 months respectively). In one case of mouse carcinoma transplantation of the tumour was successful through 4 generations, with 28 successful "takes" in 55 inoculated mice. The

transplanted tumours retained their histological features throughout, with perhaps slight increase in the degree of keratinization.

He suggests that his findings show that carcinoma must be regarded as a specific process which, under certain conditions, accompanies the hyperplastic heterotopical proliferation of the epithelium, and is not the culmination of this proliferation. Also he does not find evidence that

Fig. 3.—Mouse with intraperitoneal transplanted *Spiroptera* carcinoma 107 days after transplantation ; fourth generation.

inflammatory changes are necessarily in casual relationship to carcinoma at all, for in the mice which gave a very low percentage of carcinomatous development the hyperplasia and inflammatory changes were as, or more, marked than in the rats.

The original articles are extremely interesting, discussing every question which the experimental results bring up. R. D. P.

c. General.

Theory of Vital Phenomena.—Felix Regnault (*C. R. Soc. Biol.*, 1919, **82**, 1280–2). The organism is regarded as made up of two substances, the living substance or energid, and the organic products. The two together form the tissues and are present in variable proportions. The tissues may be grouped according to the quantity of organic products which they contain. Certain substances regarded as living are really organic products, such as the blood corpuscles and the sarcolemma of muscles. Protoplasm itself may be an organic product of the

nucleus; in any case it has an incomplete vital energy which it acquires from the nucleus. The organic products obey physico-chemical laws; the energid produces an energy special to life. J. A. T.

Blood as Food.—HASSAN EL DIWANY (*C. R. Soc. Biol.*, 1919, **82**, 1282–3). A study of the digestive tract of the medicinal leech and *Hemiclepsis tessellata*, and also of a tick (*Ixodes riduvius*), which furnishes evidence that the intestinal cells break up the molecule of hæmoglobin, giving rise not only to biliary pigments which are eliminated, but also to utilizable materials which are absorbed. The latter include fat and iron-compounds. J. A. T.

Reduction of Jugal in Mammals.—L. T. HOGBEN (*Proc. Zool. Soc. London*, 1919, 71–8). An account is given of the state of the jugal in a variety of mammalian types. "Seeing that in a diversity of isolated genera among the Placentals exhibiting every possible variety of diet and habit, and also in some of the less specialized representatives of the larger groups themselves, the jugal displays essentially the same relations as in the Metatheria—namely, extending postero-ventrally from the glenoid to the lachrymal antero-dorsally—it is hardly possible to agree with Weber that the jugal was small in the earliest Mammalia, as in the Insectivora of to-day: on the contrary, there can be little doubt that this represents the ancestral condition retained by the class till a date later than that at which the modern lines of mammalian descent had become differentiated." In Monotremes, though the arch is strong, the jugal is vestigial or absent. Reduction is common, but the reason for it is obscure. J. A. T.

New Adaptive Callosity in Ostrich.—J. E. DUERDEN (*Records of Albany Museum*, 1919, **3**, 189–95). At a certain stage in its development, the two-toed Ostrich (*Struthio*) has three toes and hints of four and five. Two or three toes have been lost, but the loss is not quite complete. When crouching the ostrich rests on the tip of its partly bent toes and upon the ankle-end of the tarso-metatarsus. There are callosities on the toes and ankle, and these occur on chicks before hatching. They are part of the inheritance. But besides the median ankle callosity there is an accessory ankle callosity, which begins to form at an early chick stage, and becomes gradually larger and coarser. This accessory pad is more practically useful than the inborn ankle callosity. But it is not known to be transmissible. "In many respects the ostrich appears to have reached senility, and it may be that structural changes resulting from external stimuli are now more likely to remain transient, instead of becoming impressed permanently upon the organism. This may assist in some measure in understanding why the later accessory ankle callosity has not become hereditary, and also why the median callosity, though unused, continues to appear generation after generation." J. A. T.

Action of Snake-poison on Blood.—B. A. HOUSSAY and A. SORDELLI (*C. R. Soc. Biol.*, 1919, **82**, 1029–31). Twenty-one different kinds of snake-poison have been studied. All these destroy the cytozyme (thrombokinase) by their lipolytic power. This soon stops

coagulation, and no blood-thrombin is formed. Some have only an anti-cytozyme power ; others have besides this a power of coagulating the plasma or solutions of fibrinogen, for they contain specific substances with an action comparable to that of the blood-thrombin. This is only an indication of the results of prolonged researches. J. A. T.

Morphology of So-called Balancers in Amblystoma.—John S. Latta (*Anat. Record*, 1919, **17**, 63–71, 4 figs.). The larvæ of some species of *Amblystoma* and a few other salamanders are, at an early stage of their development, possessed of a long villiform process on each side of the head, a little ventral to the eye and equidistant between it and the base of the external gills. They are very rigid and resistant for structures so slender, and they are almost immovable. There is no relation to the hyoid, or Meckel's cartilage, such as the external gills have to the gill-arches. A dermal bone develops in connexion with each. This is formed within its own substance, while that of the Cæcilian tentacle is independently formed and comes secondarily into relation with it. Larvæ without balancers sink into the mud when coming to rest. The balancers serve as props. They show some regenerative capacity. It seems impossible to homologize them with an external gill or with a Cæcilian tentacle. If they have any homologue in other forms, it is most likely the stalked " suctorial discs " of Triton and the viscid organs of Anuran larvæ. J. A. T.

Lympathic System of Anuran Amphibia.—Otto F. Kampmeier (*Anat. Record*, 1919, **16**, 341–53). A summary is given of an unpublished monograph on the lymphatic system in the frog and toad, with especial reference to its origin and development. The author deals with the lymphatic system in fully formed individuals, the modifications of the venous system during development, the components of the system in young tadpoles, the origin and development of the primary maxillary lymph sinus, the origin and development of the jugular lymphatics, the anterior lymph hearts, the lateral lymphatics of the trunk, the subvertebral lymphatics (thoracic ducts), the posterior lymph hearts and the lymphatics of the tail, the formation of the lymphatic capillaries, the transformation of the lymphatic vessels of the tadpole into the lymph sacs and sinuses of the adult, and the homology of the chief components of the lymphatic ground-plan in the different groups of vertebrates. J. A. T.

New Blind Fish from Texas.—Carl H. Eigenmann (*Proc. Amer. Phil. Soc.*, 1919, **58**, 397–400, 2 figs.). From an artesian well in San Antonio, Texas, a small blind catfish, *Trogloglanis pattersoni* g. et sp. n., was obtained. Some of the catfishes are nocturnal, and seek their food by touch and taste organs, and various catfishes have become blind in different parts of the world. This new one is probably derived from a genus like *Schilbeodes*. Just as the eyes of the Texan blind newt (*Typhlomolge*) are more degenerate than those of the salamanders of Missouri, so, judging from external appearances, the eyes of *Trogloglanis* are more degenerate than those of any of the blind fishes from farther north. J. A. T.

Fauna of Water-pipes and Reservoirs.—R. Kirkpatrick (*The Biology of Waterworks*, *British Museum* (*Natural History*), 1917, 2nd. ed., 1–58, 18 figs.). The fauna that may be associated with a water-supply includes fixed and free-swimming Protozoa, the two common fresh-water sponges (*Spongilla lacustris* and *Ephydatia fluviatilis*), species of *Hydra*, many kinds of worms, numerous Polyzoa, about a dozen kinds of Molluscs, a few crustaceans and insect larvæ, young eels and the like. In reservoirs there are sponges, Polyzoa, Entomostraca, larvæ of *Chironomus*, and so on. The Algæ and Bacteria are also dealt with, and the various methods of securing purity in the water-supply. The whole study is very interesting. J. A. T.

Tunicata.

Bactericidal Processes in Ascidia.—J. Cantacuzène (*C. R. Soc. Biol. Paris*, 1919, **82**, 1019–22). Specimens of *Ascidia mentula* were inoculated with a mobile Bacterium isolated from the intestine of Aplysia. The blood of the Ascidian is strongly acid, is very rich in oxydase, and contains a great variety of amœbocytes. To begin with, the circulating blood shows no other defence but intracellular digestion, but after the sixth day there is very marked agglutination of the Bacteria in direct contact with the amœbocytes. Some hyaline amœbocytes give rise to a tenuous glairy substance which immobilizes Bacteria; others containing fatty substances arrest the Bacteria that come into contact with them. The agglutination increases from the sixth to the tenth day. The phagocytosis also continues with intensity; the infection is usually mastered. The acidity and oxidizing capactiy of the blood are remarkably diminished soon after inoculation, but re-appear as the Ascidian recovers. J. A. T.

INVERTEBRATA.

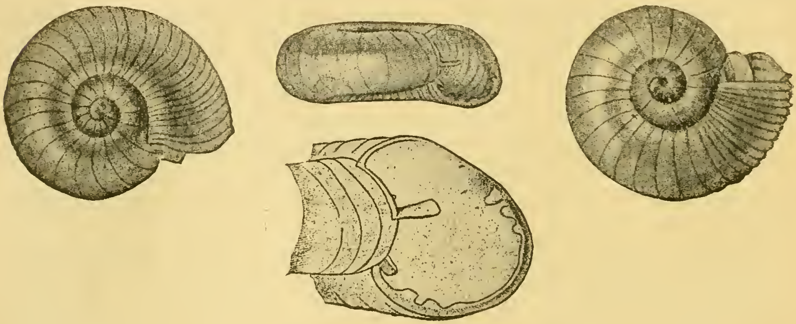
Mollusca.

a. Cephalopoda.

Orthogenetic Development of Costæ in Perisphinctinæ.—Marjorie O'Connell (*Amer. Journ. Sci.*, 1919, **48**, 450–60, 2 figs.). Using the term orthogenesis to denote the fact of progressive change in one direction in a succession of ontogenetic or phylogenetic stages, and not as a term for a theoretical interpretation of the fact, the author illustrates it in the ontogeny of the Jurassic Ammonite, *Perisphinctes cubanensis*, as regards the development of the costæ, and shows that the stages in the single individual are characteristic of the adults of earlier geological representatives of the genus. The definite direction seen in the ontogeny is not a matter of individual growth, but is some tendency inherent in the organism which leads to the same type of development in related species and in ancestors and descendants throughout Middle and Upper Jurassic time. J. A. T.

γ. Gastropoda.

Peculiar Venezuelan Land Snail.—HENRY A. PILSBRY (*Proc. Acad. Nat. Sci. Philadelphia*, 1919, **71**, 206, 1 fig.). A minute discoidal shell, concave above and below, whitish-transparent, glossy, with sculpturing of spaced radial grooves after the first half whorl. These grooves become closer near the aperture, and in the largest and freshest specimens they are occupied there by projecting riblets, which may be partly cuticular and deciduous. The specimens were 0·55 mm. high and 1·6 mm. in diameter, and were obtained by sifting leaf debris. The affinities remain uncertain, as it is very unlike any described form. It doubtless belongs to a new genus, provisionally placed near *Proserpinula*



Three views of *Xenodiscula venezuelensis*, and the aperture more enlarged.

or *Volvidens*, both Antillean genera. The name proposed is *Xenodiscula venezuelensis* g. et sp. n. J. A. T.

Gastropods of Old Lake-beds in Upper Burma. — NELSON ANNANDALE (*Records Geol. Survey India*, 1919, **50**, 209–40, 3 pls.). Attention is called to parallel evolution or convergence on a large scale in the shells of fresh-water Gastropods of different regions and epochs. The evolution of the genus *Taia*, a peculiar off-shoot of the Viviparidæ, with peculiarly ridged, nodulose, and even spiny shells, is exactly parallel to, but quite independent of, that which produced *Margarya* in the lakes of south-western China, and also that which, at an earlier period and in a distant country, resulted in a large series of species of *Vivipara* and *Tulotoma* with a similar type of shell in the Vienna basin. But *Taia* is proved by the peculiar structure of its columellar callus to be only analogous, not homologous, with the Austrian and Chinese forms. The genus *Vivipara* has, in fact, again and again, in diverse countries and at different periods, manifested, when left undisturbed and isolated for longer periods, a tendency to produce shells ornamented with smooth spiral ridges. With further evolution these ridges become at first undulated on the surface, then granular or nodular, and finally

in a few instances (e.g. the living *Taia intha* and some forms of *Margarya melanoides*) are transformed into series of peculiar squamous spines. Moreover, *Vivipara* is not the only genus in which this tendency appears. It is shown to some extent by the Neritidæ of Tertiary beds in Cos, and in a more striking manner by the Hydrobiidæ or Paludestrinidæ of the same period and region, and by those still living in the Yangtse valley. A number of new forms are described.

J. A. T.

Action of Veratrin on Snails and Slugs.—G. Colosi (*Arch. Zool. Expér.*, 1919, **58**, *Notes et Revue*, 45–8, 2 figs.). If a specimen of *Helix* or *Limax* be immersed in water with a few drops of weak solution of veratrin there is protrusion and paralysis of tentacles, buccal mass and penis, while the rest of the body pulsates violently and then becomes rigid. There appears to be a great increase of internal pressure in the anterior region of the body. The protrusion of the penis after veratrin treatment showed that *Limax maximus* is as regards this organ very different from *L. cinereo-niger*. J. A. T.

Arthropoda.

a. Insecta.

Blood-sucking Insects of the Philippines.—Charles S. Banks (*Philippine Journ. Sci.*, 1919, **14**, 169–89). A useful survey of the different kinds of blood-sucking insects: bed-bugs, lice, forest flies (Hippoboscidæ), bat flies, mosquitoes, horse flies (Tabanidæ), moth flies (Psychodidæ), true flies (Muscidæ), buffalo gnats (Simuliidæ), midges (Chironomidæ), fleas, water-bugs, rubber flies (Mydaidæ and Asilidæ), which capture and suck other insects, and the small fringe-winged Thrips. Blood-sucking mites and ticks are also referred to for the sake of completeness. J. A. T.

Trapping of Insects by an Asclepiad.—H. Ricome (*C.R. Soc. Biol.*, 1919, **82**, 1045–7). Many insects, such as hawk-moths and bees, are trapped by an Asclepiad of the genus *Arauja*, which is cultivated in gardens. The flower is adapted to pollination by insect visitors, and all goes well if the insect keeps its proboscis between the stamens and the petals. It carries away the pollinia on its tarsal joints. But if the proboscis is inserted between one of the retinacula and the contiguous edges of two adjacent anthers it gets caught in a viscous groove of the retinaculum. There is no reason to believe that this means more than that European insects are not adapted to an exotic flower. Perhaps in the natural conditions the trap eliminates unwelcome visitors.

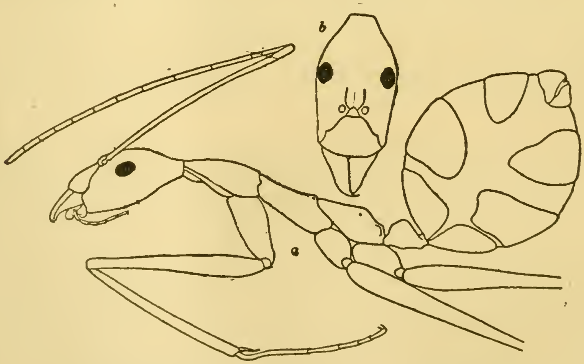
J. A. T.

Larva of Pontania vesicator.—Rob. Staeger (*Revue Suisse Zool.*, 1919, **27**, 333–46). This gall-wasp larva makes bean-shaped galls on the leaves of *Salix daphnoides*. The presence of the egg is not enough to cause the irritation; the larva is necessary. If a gall be cut open, the larva will seek another open one if that promises food. The

full-grown larva takes to sandy and powdery soil, and makes an oval hollow. It spins a network with strong compound ribs and more delicate tissue between these, and attaches this to little stones in the hollow. Soil-particles also become entangled in the web. As the result of often-repeated somersaulting movements it makes an oval cocoon. The first pair of legs helps in the cocoon-forming. Damaged cocoons are repaired, but not if the damage extends to half of the cocoon. An excised end can be replaced apart from the substratum, and in the absence of substratum-particles thick strands are made by compounding many single threads. The plasticity of the instinctive behaviour is of great interest; the instinct is still capable of development. J. A. T.

Poison of Predatory Hymenoptera.—A. Ch. Hollande (*C.R. Soc. Biol.*, 1920, **83**, 9–11). Roubaud has maintained that the poison of predatory Hymenoptera, such as wasps, has a twofold effect, producing paralysis and preventing rapid decomposition after death. Hollande has studied twenty-three paralyzed Geometrid caterpillars taken from the nest of some Eumenid or the like. They were in perfect preservation, and they reacted to the touch of a needle by slight movements of the end of the abdomen. Careful examination of the tissues showed that the cells were quite normal in their staining reactions. But this need not be ascribed to any preservative effect of the poison; it is simpler to suppose that while the poison anæsthetizes the nerve-cells the ordinary cells of the body remain alive. J. A. T.

Australian Honey-ants.—W. M. Wheeler (*Proc. Amer. Acad. Arts and Sciences*, 1915, **51**, 255–86, 12 figs.). Observations on the



Leptomyrmex varians Emery var. *ruficeps* Emery.
a. Replete worker. *b.* Head from above.

singular ants of the genus *Leptomyrmex*. The worker is marked by the extraordinary attenuation and elongation of all parts of the body except the abdomen. There is a very high development of the proventriculus, which functions as a valve between the ingluvies or crop and the ventriculus or true stomach. The insects have the habit of

storing large quantities of liquid food in the crop. In *L. unicolor*, which has not this habit, the proventriculus is much smaller, its valves are proportionally shorter, and the layer of musculature is much thinner. The venation of the fore-wing in the male is unlike that of any known ant. Another peculiarity is the absence of a queen or female caste in any of the known species. The nests are in the ground or in great rotten logs, but the large size of the nests, and the very slender and frail stature of the ants, suggest that the insects take possession of cavities made and abandoned by lizards or small marsupials. When walking or running they carry the gaster bent up at right angles to the long thorax, hence the name "motor-car ants." They forage singly, and are highly carnivorous, sucking the juices of their victims, which are usually insects. Except in *L. unicolor*, all colonies showed a certain percentage of "repletes" with the gaster distended with fluid; they are able to run about, but they devote themselves very sedulously to the larvæ or pupæ. The larvæ are very peculiar, with vestigial mandibles; they imbibe liquid food. The adults have a rancid-butter odour. The probability is that one or more fertile workers in each nest supply the eggs. J. A. T.

Myrmecophily in Uncaria.—E. DE WILDEMAN (*C. R. Soc. Biol.* 1919, **82**, 1076–8). In a species of this Rubiaceous genus the lower internodes of the lateral branches show a hollow swelling tenanted by ants. The cavity is continued at its base into a cavity of the adjacent internode of the main stem. There are numerous regularly arranged rounded apertures leading into the myrmecodomatia. It is suggested that the frequency of myrmecodomatia in plants growing in marshy places or by the sides of rivers has to do with the unsuitability of the soil for underground nests. J. A. T.

Immunity of Caterpillars of Galleria melonella.—S. METALNIKOFF (*C. R. Soc. Biol.*, 1920, **83**, 119–21). These beehive caterpillars were injected with various pathogenic microbes fatal to higher animals, but seemed quite refractory. This applies to microbes like those of tetanus, tubercle, diphtheria, plague, and yet the caterpillars are very susceptible to saprophytic and slightly pathogenic microbes. J. A. T.

Adjustments of Lymantria dispar.—ARNOLD PICTET (*MT. Schweiz. Entomol. Ges.*, 1919, **13**, 20–54). An account is given of the life-history of this moth and of its adjustments to unusual conditions. For three consecutive generations the caterpillars were fed on leaves of Conifers. They ate the leaves, but the result was an enfeebling of the race, as regards growth, reproductive success, and resistance to disease. In many cases reproduction became impossible. The low temperature of the environment is partly responsible, but the diet is also prejudicial. Lasting adjustments to poplar, horse-chestnut, and *Mespilus germanica*, and also the dandelion and *Onobrychis sativa*, seem to be quite practicable. J. A. T.

Chromosomes in Tiger-beetles. — W. M. GOLDSMITH (*Journ. Morphol.*, 1919, **32**, 437–87, 10 pls.). The early spermatogonia occur in

groups of syncytia, each syncytium behaving like a unit of cellular activity. The early oogonia have very definite cell walls. The spermatogonial number of chromosomes for five species of *Cicindela* is twenty-two. The oogonial and female somatic number is twenty-four. Definite pairs of chromosomes are readily recognized in every clear spermatogonial, oogonial, and somatic metaphase plate. The eleven chromosomes of the first spermatocyte are very irregular in shape and especially difficult to figure. Autosomes in the form of complete and incomplete V's of various sizes, rings, hooks, and rods were figured from side views of the spindles. The secondary spermatocyte numbers of chromosomes are ten and twelve, much more uniform than those of the first spermatocyte. The "sex-chromosome" appears on the first spermatocyte spindle as a double body, the two elements (X, x) of which are very unequal in size and loosely united. These elements neither divide nor separate in the first division, but pass to one pole in advance of the autosomes, giving secondary spermatocytes with ten and with twelve ($10 + X + x$) chromosomes respectively. In the second division the components of the bipartite body separate. The germ cells of the female seem to contain approximately twice as much X chromatin as is found in those of the male. J. A. T.

Intestinal Glands in Larval Insects.—J. Pantel (*La Cellule*, 1914, **29**, 393–429, 1 pl., 2 figs.). In larvæ of Ptychopteridæ there are five Malpighian tubes, two directed forwards and partially transformed into large sacs distended with granular calcareous concretions, the others directed backwards. The minute structure of the tubes is described. The tubes are bound to other structures by muscular fibres. During the pupation the posterior tubes pass without disintegration into the imaginal structure; the sacciform tubes expel their contents into the intestine, whence it is got rid of, and pass into the imaginal structure; the muscular fibres degenerate. The calcareous granules are to be regarded simply as products of renal excretion. J. A. T.

Dipterous Parasite of Peaches.—J. Legendre (*C. R. Soc. Biol.* 1920, **83**, 8–9). Madagascar peaches are much spoiled by amber-coloured maggots of *Ceratitis capitata*, often called the "orange fly," which is well known in the Mediterranean region, in Africa, Mauritius and Reunion. J. A. T.

Dorsal Blood-vessel in Larval Muscids.—J. Pantel (*La Cellule*, 1914, **29**, 318, 3 figs.). Description of the minute structure of the posterior region of the dorsal blood-vessel in larvæ of *Thrixion*, *Compsilura* and *Ceromasia*, showing differences in detail in these types. J. A. T.

Cyrtopogon platycerus Villeneuve.—J. Escher-Kündig (*MT. Schweiz. Entomol. Ges.*, 1919, **13**, 54–9, 3 pls.). A description of the hitherto unknown male of this rare predatory fly, which the author found at Novaggio, in the Malcantone Valley. Its sex dimorphism is compared with that of *C. longibarbus* Löw., and a careful description is given of both sexes. J. A. T.

Midge Infesting Potatoes.—EDITH M. PATCH (*Journ. Econ. Entomology*, 1917, **10**, 472–3, 1 pl.). A Chironomoid larva, probably a species of *Camptocladius*, was found as a miner in potatoes in Maine, a very unusual habit which may have been induced by some peculiar local condition. J. A. T.

Parasite of Blueberry Maggot.—W. C. WOODS (*Canadian Entomologist*, 1915, **47**, 293–5, 1 pl.). From apple maggots or "railroad worms" (*Rhagoletis pomonella* Walsh), infesting the fruits of the blueberry in Maine, there emerged specimens of a Braconid (*Biosteres rhagoletis* sp. n.) which are described by E. A. Richmond in this paper. J. A. T.

Philippine Species of Phlebotomus.—CHARLES S. BANKS (*Philippine Journ. Science*, 1919, **14**, 163–7, 1 pl.). A description of *Phlebotomus nicnic*, a minute moth-fly (Psychodid), about 2 mm. in length, which gives an extremely severe bite, more painful than that of most mosquitoes. Its grey shaggy appearance makes it difficult to be seen against the skin. The genus is represented in India and Ceylon, but this is the first Philippine record. It is believed that the "nicnic" breeds in kitchen drains. The tiny fly is a serious factor in human existence in the Philippines, and is not improbably an agent in disease transmission. J. A. T.

Psyllid Gall on Juncus.—EDITH M. PATCH (*Psyche*, 1916, **23**, No. 1, 1 pl.). The normal compact inflorescence of Juncus is sometimes replaced by a monstrous tassel of the nature of a gall. It is shown that this is due to the young stages of a beautiful little Psyllid, *Livia maculipennis*, which Fitch described in 1857 as frequenting swampy places. J. A. T.

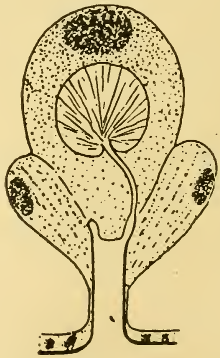
Meadow Plant-bug.—HERBERT OSBORN (*Journ. Agric. Research*, 1918, **15**, 175–200, 1 pl.). An account of *Miris dolabratus*, common in timothy meadows in the eastern United States during the past forty years, and now distributed as far west as Illinios and as far south as Kentucky. It is believed to be of European origin. It feeds on cultivated grasses. There are dimorphic females, about 90 p.c. short-winged, and the rest long-winged. The species hibernates in the egg-stage. The egg is thrust into the stem of grass or clover and remains protected in the hollow before hatching. Rotation and other practical measures are suggested. The known natural enemies are spiders, the predacious damsel bugs, a Tachnid fly, and a fungus. J. A. T.

Glyphotælius punctatolineatus.—F. RIS (*MT. Schweiz. Entomol. Ges.*, 1919, **13**, 17–9). This is one of the most notable of Palæarctic Trichoptera, remarkable in size and beauty. The author reports its occurrence among the Bog-bean (*Menyanthes*) leaves by the side of an Alpine lake (at an elevation of 1302 metres) in Toggenburg. The gelatinous egg-masses were attached in thousands to the leaves, but the imagines were scarce. It is probable that they are nocturnal in habit. J. A. T.

Ceriparous Cells in Lecanium persicæ.—G. Teodoro (*Bull. Soc. Entomol. Ital.*, 1919, **50**, 23–7). There are free ceriparous cells or cerodecytes in the hæmolymph, and there are others which occur in groups contiguous to a tracheal trunk (the so-called hypo-stigmatic glandular cells). The two sets differ not only in localization but also in their minute structural details. J. A. T.

Coccidæ of South-western United States. — Gordon Floyd Ferris (*Leland Stanford Junior University Publications*, 1919, 1–68, 38 figs.). An account is given of a large number of Coccidæ collected in the arid regions of the south-western portion of the United States. Numerous new forms are recorded and defined, and numerous previously named forms are re-described. J. A. T.

Mealy Bugs of California.—Gordon Floyd Ferris (*Leland Stanford Junior University Publications*, 1918, 1–77, 3 pls.). In addition to systematic descriptions there is a discussion of the taxonomic



Section through a wax-gland of *Eriococcus adenostomæ* Ehrb.

value of the characters of the antennæ, legs, dorsal ostioles (from which globules of secretion exude), cercarii (marginal groups of pores and differentiated spines from which arise the characteristic tassels or filaments of wax), the pores and ducts of the wax-secreting glands, and the setæ of the body. J. A. T.

Mound-building Termites of Philippines. — Leopoldo B. Uichanco (*Philippine Journ. Sci.*, 1919, **15**, 59–65, 4 pls.). The mounds make by species of *Termes* in the Philippines rarely exceed 2 metres in height. Beneath the thick outer crust of clay there are numerous coral-like "fungus gardens" of woody and plaster-like material. The "mushrooms" may crop out on the surface and are eaten by man. Counts of swarms gave an average of five females to a hundred males. The swarms are thinned by bats, birds, lizards and other enemies. After shedding their wings the couples run about, and a pair seem able to make a new colony. In about three months there

are workers enough to make a fungus garden. "The queen's life has been estimated to last about twenty years." The male is short-lived. The "guests" of the termitary are largely scavengers. J. A. T.

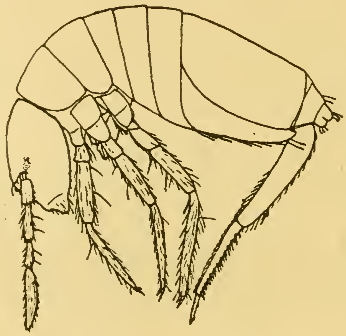
The Genus Krisna.—C. F. Baker (*Philippine Journ. Sci.*, 1919, **15**, 209–20, 5 pls.). A common evening visitor to one's table-lamp almost anywhere in the Malaisian countries is a vividly virescent leaf-hopper of the genus *Krisna*, a half inch, more or less, in length, and with the transverse fore margin of the vertex black or a bright reddish colour. This is likely to be *Krisna strigicollis*, but there are many other species. The present paper deals with the genus *Krisna* and the allied genus *Gessius*, both members of the tribe Stegelytraria.
J. A. T.

Jumping Plant-lice of the Palæotropics and the South Pacific Islands.—David L. Crawford (*Philippine Journ. Sci.*, 1919, **15**, 139–207, 3 pls., 3 figs.). An extension of our knowledge of the Psyllid or Chermid Homoptera of these regions. The author takes a taxonomic survey of the family and describes numerous new species. There are some very interesting evolutionary features in the Psyllid fauna of certain island groups. Thus, in the Hawaiian Archipelago, thirteen of the fifteen known species are apparently derivatives of one species long ago established there. Some of these species have diverged so far from the ancestral type, a *Trioza*, that two other generic groups embrace them. In the Malay Archipelago the genus *Megatrioza* is abundantly represented, but extends into the Philippines and south into Australia, and one species has found its way as far south as the Hawaiian Islands. Several other genera appear to have sprung from this one. Economically the family is of less importance than the Aphididæ and much less than the Coccidæ. Buckton's *Psylla isitis* (probably the same as Crawford's *Arytaina punctipennis*) is a pest on indigo; and *Euphalerus citri* on citrus trees. J. A. T.

Hermaphroditism in Lice.—D. Keilin and G. H. F. Nuttall (*Parasitology*, 1919, **11**, 279–328, 6 pls., 28 figs.). No fewer than 155 hermaphrodites of *Pediculus humanus* were studied. They were of various degrees, all of them "mixed gynandromorphs," and including representatives of Cockayne's three groups—genetic, primary somatic, and secondary somatic hermaphrodites. The hermaphroditism is often accompanied by secondary malformations—viz. fragmentation of the dorsal bands, disoriented proliferation of the genitalia of one sex, and various invaginations, devaginations and prolapses of the genitalia. These prolapses, in the male organs, are due to atrophy of the retractor muscles and basal plate, whilst in the female organs the prolapses are either due to the abnormal development or to coital traumatism. The structure of the hermaphrodites indicates that they may be either sexually non-functional or functional, serving, in the latter case, as males or as females in respect to copulation. In "wild" lice the few lots which comprised hermaphrodites had 0·2 to 8 p.c. of them. In the progeny of crosses between *P. capitis* and *P. corporis*, some families gave over 20 p.c. of hermaphrodites (always associated with a great decrease in the pro-

portion of females to males). Other abnormalities not connected with hermaphroditism are discussed. It is shown that the *P. capitis* may acquire all the characters of *P. corporis;* the two are but races of *P. humanus.* J. A. T.

Abor Collembola.—G. H. Carpenter (*Records Indian Museum*, 1917, **8**, 561–8, 3 pls.). A new genus, *Cyphoderopsis*, is established for *C. kempi* sp. n., a blind, pale, scaled spring-tail, found by Stanley W. Kemp under stones at Rotung, North-East Assam, at an elevation of 1400 feet. The spring has a rigid tapering dens, with a double row of strong spines and a delicate distal scale-appendage. The mucro is elongate and narrow, with terminal and dorsal teeth. This remarkable



Cyphoderopsis kempi g. et sp. n. Lateral view.

genus resembles *Cyphoderus* in many respects, and may be regarded as a connecting link between typical Cyphoderini and the Paronellini. Its features are so striking that Carpenter has no hesitation in establishing the new genus and species on a single specimen. New species of *Protanura*, *Lepidocyrtus*, and *Paronella* are described. J. A. T.

γ. Myriopoda.

Occurrence of Craterostigmus tasmanianus in New Zealand.—Gilbert Archey (*Trans. New Zealand Inst.*, 1916, **49**, 319–20). This unique genus of centipedes, the sole representative of the order Craterostigmophora, occupies according to Pocock an intermediate position between Scolopendromorpha and Lithobiomorpha. It has hitherto been known only from two specimens collected on the summit of Mount Rumney, Tasmania. It has now been found abundantly within a certain range in New Zealand. "The occurrence of such an archaic form as *Craterostigmus* in both New Zealand and Tasmania is of considerable interest, for it may be regarded as having some significance in connexion with the question of a former land connexion between these two countries." J. A. T.

Lithobiomorpha of New Zealand.—GILBERT ARCHEY (*Trans. New Zealand Inst.*, 1916, **49**, 303–18, 46 figs.). Hitherto only six species of this sub-order of centipedes have been known from New Zealand. The author adds three new species of *Lamyctes*, two new species of the genus *Paralamyctes* (hitherto not known to be represented in New Zealand), and two new species of a new genus, *Wailamyctes*. A key to the families is given. J. A. T.

Revision of Spirobolidæ.—J. CARL (*Revue Suisse Zool.*, 1919, **27**, 377–404, 42 figs.). An account of *Rhinocricus*, *Messicobolus*, *Saussurobolus* g. n., *Xenobolus* g. n., *Chelogonobolus* g. n., and *Spirobolus*, with especial reference to the minute structure of the gonopods, which appear to have much systematic value. J. A. T.

Alpine Leptoiulidæ.—WALTER BIGLER (*Revue Suisse Zool.*, 1919, **27**, 283–333, 2 pls., 7 figs.). An account of seven Alpine species, four of which are new. The specific characters are crisply defined, but the group shows a very distinct unity in certain structural features, notably as regards the copulatory apparatus. The evolutionary interest of the unity amid diversity is discussed in detail. J. A. T.

Revision of Glomeridæ.—F. SILVESTRI (*Records Indian Museum*, 1917, **13**, 103–51, 35 figs.). A systematic report on Indian Glomeridæ, a family of Oniscomorph Diplopoda. The author deals with four genera—*Apiomeris*, *Rhopalomeris*, *Hyperglomeris* g. n., and *Dinoglomeris* g. n.—and 26 species. J. A. T.

δ. Arachnida.

The Genus Oxus—CHARLES D. SOAR (*Journ. Quekett Micr. Club*, 1919, **14**, 1–6, 1 pl.). A revision of this genus of water-mites, of which there are three British representatives, *O. plantaris* Sig. Thor., *O. ovalis* (Müll.) Kœnike, and *O. strigatus* (Müll.) Piersig. J. A. T.

New Species of Arrhenurus.—RUTH MARSHALL (*Trans. Amer. Micr. Soc.*, 1919, **38**, 275–81, 3 pls.). About 90 genera of Hydrachnidæ are now recognized, with some 800 species. About one-fourth of these species belong to the genus Arrhenurus. Fifty-five have been described for North America, chiefly from the Upper Mississippi Valley. This paper adds one new species from Wisconsin, six from South America, and two from China. J. A. T.

ε. Crustacea.

Commensalism in Hermit-crabs.—R. P. COWLES (*Philippine Journ. Sci.*, 1919, **15**, 81–9, 1 pl.). Observations on the partnership between hermit-crabs and sea-anemones. The careful transfer of the sea-anemones from the old shell to the new one was observed in two species. Considerable inaccuracy in the attachment was sometimes seen. In some cases the anemones attach themselves as larvæ to the mollusc shell. The behaviour of the hermit-crabs gives evidence of some inherited nervous condition which directs the actions. We must not credit the

hermit-crab with understanding what it does, "yet, assuming that the remarkable behaviour of the hermit is due to instinct—that is, to an 'inherited combination of reflexes' which have been so brought together by the nervous system that the behaviour has become fixed and adaptive in the species—it is extremely difficult to conceive how it has acquired these habits." J. A. T.

Arctic Decapods.—Arvid R. Molander (*Arkiv f. Zool.*, 1914, **9**, 1 pl.). A synopsis is given of the species of *Spirontocaris*, and an account of *S. recurvirostris* sp. n., with a long rostrum sharply bent, with its upper edge dentated, aud with the base free from spines over the orbits. A hermit-crab, *Eupagurus porcellanus* sp. n., from the Behring Sea, is marked by the completely smooth surface of the carpopodite and propodite of the right forceps. Both these joints are strongly developed, and the propodite is rectangular. J. A. T.

Variability of Potamon edule.—A. Matteotti (*Bull. Soc. Entomol. Ital.*, 1919, **50**, 12–17, 2 figs.). A study of the variations in this Crustacean as regards the dimensions and shape of the abdomen and the characters of the third pair of maxillipedes. A distinction is drawn between those connected with the age of the animal and those which are true variations. J. A. T.

New Species of Lernæopoda.—W. H. Leigh-Sharpe (*Parasitology*, 1919, **11**, 256–66, 7 figs.). A description of *L. mustelicola* sp. n., from the smooth hound (*Mustelus vulgaris*). Only the female was obtained. Among the specific characters the following may be noted: cephalothorax pigmented with black dots; proximal end of second maxillæ swollen; ovisacs short (4 mm., about two-thirds length of trunk); abdominal appendages short (1 mm., about one-sixth length of trunk); the base of the mandible bears a hooked projection on its inner side. The new species is compared with *L. scyllicola*, *L. galei*, and *L. globosa*. Strange tumour-like growths from the cephalothorax of *L. scyllicola* are described, and a detailed account is given of the antennæ of this species, which bear what may be photo-receptors. These also occur iu *L. galei* and *L. mustelicola*, but apparently not in *L. globosa*, which lives in darkness. J. A. T.

Annulata.

Stomodæum of Lumbricidæ.—J. J. Menzi (*Revue Suisse Zool.*, 1919, **27**, 405–76, 2 pl., 13 figs.). The stomodæum begins as a narrow blind ectodermic tubule, with which the endoderm has no communication. It grows back to the fourth segment, and histolysis occurs at the junction of ectoderm and endoderm. A muscular cushion appears dorsal to the stomodæum, and is the first hint of the future pharynx, which is almost certainly ectodermic in origin. The stomodæum shows at first a continuous internal ciliation, but this embryonic character disappears and the cilia are replaced by a cuticle. The pharynx as it grows extends as far as the sixth segment. There is general agreement that an ectodermic invagination forms the mouth cavity in the regenerative process;

there is considerable discrepancy in regard to the pharynx. The author presents an interesting summary of the data which previous observers have furnished in regard to the correspondence or lack of correspondence between the embryonic and the regenerative development of the pharynx. He is not inclined to draw embryological conclusions from regenerative processes. J. A. T.

North American Oligochæts.—PAUL S. WELCH (*Trans. Amer. Microscop. Soc.*, 1919, **38**, 175–88, 1 pl.). Continuing his studies on Mesenchytræids, the author gives an account of *Mesenchytræus hydrius* sp. n., from an altitude of 3,400 feet on Mount Rainier. The specimens crawled about in sand in slowly moving water, in close proximity to melting snow. The colour is light yellow; pigmentation is entirely absent. A description of the reproductive system is given. A curious feature is the crossing of the elongated spermothecæ. They extend from segment 10 forwards, and at the posterior end of segment 5 or the anterior part of 6, the right organ crosses to the left side of the body and the left organ to the right side. A key is given to the species of *Mesenchytræus* known to occur in North America. J. A. T.

New Echiuroid Genus from Great Barrier Reef.—T. HARVEY JOHNSTON and O. W. TIEGS (*Proc. Linn. Soc. N.S.W.*, 1919, **44**, 213–30, 3 pls.). A description of *Pseudobonellia biuterina* g. et sp. n., an interesting relative of *Bonellia*, but very distinct. The female shows a *Bonellia*-like form, two to four setæ, two well-developed and functional uteri, simple anal glands opening directly into the rectum, an ovary in a posterior transverse position, and a siphon associated with the intestine. There is an invagination or male tube within which a single male is lodged. The male is extremely degenerate and apparently partly fused to the female. It shows two functional vesiculæ seminales; there are no hooks. J. A. T.

Nematohelminthes.

Anomaly in Ovary of Ascaris megalocephala.—J. DRAGOIU and E. FAURÉ-FREMIET (*C.R. Soc. Biol.*, 1920, **83**, 123–5). An adult female, about 20 cm. in length, showed in the ovary no trace of germ-cells. The lumen contained only mucus. It is probable that there had been in the course of development a suppression of the initial cell which gives rise to the germinative line, as contrasted with the somatic lines of the ovarian wall. J. A. T.

Life-history of Ascaris suilla — F. H. STEWART (*Parasitology*, 1919, **11**, 385–7, 1 pl.). Continuing previous investigations, the author reports that after giving about 22,000 ripe eggs of *A. suilla* to each of two sucking-pigs numerous larvæ were found in the small intestine of one (fourteen days after infection), but none in the other (nineteen days after infection). In another case about 50,000 ripe eggs were given, and thirty-one days after no worms were found in the intestine. An account is given of the structure of a larva of *A. suilla* taken from the intestine of a pig fourteen days after infection. J. A. T.

Refractive Body of Spermatozoon in Ascaris canis.—A. C. Walton (*Proc. Amer. Acad. Arts and Sci.*, 1916, **52**, 255–66, 2 pls.). The "refractive body" of the spermatozoon is formed in the vas deferens by a fusion of the "refringent vesicles" of the spermatocytic stages. These "refringent vesicles" are formed from the cytoplasm of the spermatocytes through the action of small extruded granules of karyochromatin, the "karychondria" of Wildman. The "refractive body" in *Ascaris canis* takes no part in the fertilization of the egg other than as a source of food supply to the spermatozoon between the time of copulation and the time of "insemination" (surely an incorrect use of the word, instead of fertilization). Plastochondria, the so-called mitochondria, which cluster round the nucleus of the spermatozoon, are not plasma-bearers of hereditary factors. They are partly of plastosomal and partly of karyochondrial origin, being formed in the "refringent granules." J. A. T.

New Nematode from a Baboon.—C. H. Treadgold (*Parasitology*, 1920, **12**, 113–34, 2 pls.). A description of *Loa papionis* sp. n., occurring in larval and adult conditions in subcutaneous tissues and some other regions of *Papio cynocephalus* from French Guinea. The intermediate host is unknown. The larvæ, unlike those of the human parasite *Loa loa*, show no diurnal periodicity. Some adults show bacterial disease. There is evidence of both traumatic and toxic action on baboons. The ova and larvæ are described, and a number of structural features are elucidated. The so-called excretory and genital cells of the larvæ, as described by Rodenwalt, are frequently not individualized at all; their outline, when present, may be double or incomplete; no chromatin or nucleus could be seen. Manson's "buccal apparatus" would seem to be nothing more than an optical illusion. J. A. T.

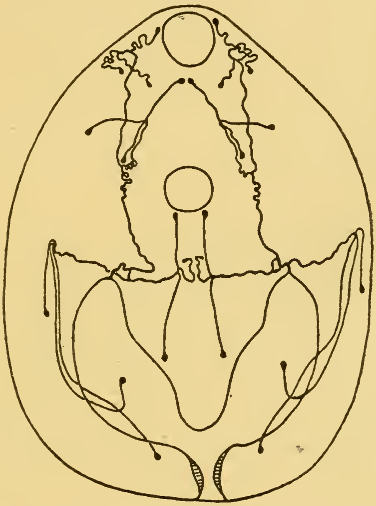
Platyhelminthes.

Swiss Helminths.—O. Fuhrmann (*Revue Suisse Zoologie*, 1919, **27**, 353–76, 1 pl., 11 figs.). An account of *Notocotylus seineti* sp. n., an interesting form from the cæca of *Querquedula querquedula*; *Davainea urogalli* (Modeer); *D. tetraonensis* sp. n. from *Tetrao urogalli*; and *D. proglottina* Dav., which is probably the same as *D. varians*. J. A. T.

Pigmentation of a Polyclad.—W. J. Crozier (*Proc. Amer. Acad. Arts and Sci.*, 1917, **52**, 725–9, 1 pl.). In a Polyclad Turbellarian belonging to the genus *Pseudoceros*, found in association with various Tunicates, e.g. *Ectinascidia*, there is a parallel between the coloration of the Turbellarian and that of the Tunicate. At least a good fraction of the colour is due directly to the food in the alimentary canal; and it seems practically certain that the three colour varieties studied are "physiological varieties" (or modificational forms) of one species, feeding on different hosts. The readiness with which these Polyclads return to their own particular kind of Tunicate is interesting. J. A. T.

New Trematode from Little Brown Bat. — Ernest Carroll Faust (*Trans. Amer. Microc. Soc.*, 1919, **38**, 209, 1 pl., 1 fig.). A new

genus, *Acanthatrium*, is established for *Lecithodendrium sphærula* Looss, and for a new form (*A. nycteridis*) found in the intestine of a bat (*Nycteris borealis*) in Illinois. The genus includes small-sized Brachycœliinæ, spherical to pyriform, with a genital atrium lined with numerous integumentary spines; prostate glands numerous; testes pre-acetabular, in a plane with the genital pore; vitellaria anterior to the digestive cæca; excretory system with four groups of flame-cells of three each for each half of the body. The fourfold grouping may be a common



The excretory system of *Acanthatrium nycteridis* g. et sp. n.
The natural size of the fluke is 0·185–2 mm. in length by 0·15–0·16 mm. in breadth.

denominator of the several sub-families of the Brachycœliidæ. From the genus *Lecithodendrium* it is necessary to separate off another new genus, *Mesodendrium*, for *L. granulosum*, *L. hirsutum* and *L. urna*.

J. A. T.

Cœlentera.

Development of Sea-anemones.—James F. Gemmill (*Phil. Trans.*, 1920, **209**, Series B., 351–75, 3 pls.). A study of *Metridium dianthus* and *Adamsia palliata*. Segmentation is equal or subequal, from the first in *M.*, beginning with the 4-celled stage in *A.* There is a bilaminar, greatly folded, and subsequently often saucer-shaped pre-blastula stage in *A.* The blastulæ are spherical hollow in *M.*, filled in *A.*, with a central non-nucleated or sparsely nucleated trophic mass, produced by constriction of the inner yolky ends of the cells of the blastula wall. In both *M.* and *A.* embolic gastrulation occurs, sometimes assisted by unipolar cell proliferation, and in *A.* the central trophic material gradually

passes through the in-pushing endoderm into the cavity of the archenteron. In *M.* a small amount of "mesoderm" is formed from the developing endoderm cells. The blastopore becomes the mouth, and in early stages is oval or slit-like and slightly to one side. The larva of *M.* has an aboral tuft of long cilia and an aboral sense-organ. The stomodæum forms by in-folding of epiblast at the blastopore, with subsequent elongation by interstitial growth. There is a definite 8-mesentery stage; the sulco-lateral mesenteries are the first to appear; the mesenteric filaments contain downgrowths of stomodæal epiblast. The planula is provided with stinging cells. The young *M.*, prior to aboral fixation and tentacle formation, creeps about, mouth downwards, with the stomodæum more or less everted. It is probable that feeding takes place at this time, as in the immediately preceding late planula stage. It is suggested that the Anthozoa acquired an ectodermic stomodæum and the rudiments of bilateral symmetry during a creeping ancestral stage, from which the Turbellaria and the higher Metazoa may have been derived.

J. A. T.

Northern and Arctic Alcyonaceæ.—ARVID R. MOLANDER (*K. Svenska Vetenskapsakad. Handlingar.*, 1915, **51**, 1–93, 3 pls., 14 figs.). Part of a systematic survey, with special attention to localities and depths. As regards structure, emphasis is laid on the details of the canal-system, on the formation of the calyx, aud on the spicules. Descriptions are given of *Anthelia borealis* (Dan.), *A. fallax* Broch., *Clavularia arctica* (Sars.), *C. stormi* Dan., *Xenia wandelii* Jungersen, *Anthomastus purpureus* (Kor. & Dan.), *A. agaricus* Studer, *Alcyonium digitatum* and two varieties, *Sympodium catenatum* (Forbes), five species of *Gersemia* and varieties, six species of *Eunephthya*, including *E. groenlandica* sp. n. J. A. T.

Spitzbergen Alcyonacea.—A. R. MOLANDER (*Zool. Ergebnisse Schwed. Exp. Spitzbergen*, in *K. Svenska Vetenskapsakad. Handl.*, 1918, **54**, No. 9, 1–19, 1 fig.). An account is given of *Gersemia rubiformis* (Ehrenberg), *G. uvæformis* (May), *G. clavata* (Dan.), *G. clavata* var. *crassa* (Dan.), *G. fruticosa* (M. Sars.), *G. fruticosa* var. *rigida* Molander, *G. mirabilis* (Dan.), and *Eunephthya glomerata* Verrill. The species of *Gersemia* are difficult to deal with, and this further study is very welcome. Special attention is given to the distribution of the species. J. A. T.

New Genus of Tetracoralla.—G. M. EHLERS (*Amer. Journ. Sci.*, 1919, **48**, 461–7, 3 figs.). A new genus and species, *Heterolasma færstei*, from the Niagaran of Michigan, seems to represent an aberrant departure from *Zaphrentis*, differing (like *Amplexus*) in not having the septa reach the centre of the corallum. The genus is also characterized by its wide tabulæ, its shape (a short cone with more or less horizontally extended margins), and the diversity in the form of the septa. J. A. T.

Development of Colonies of Aglaophenia.—MAURICE BEDOT (*C.R. Soc. Phys. His. Nat. Genève*, 1919, **36**, 50–7, 4 figs.). The author

distinguishes a primitive stem (A), without hydrocladia, with a naked basal region and a region with cauline hydrothecæ. When the hydrocladia begin to be formed, the colony has, for a time, a transitory stem (B) in which may be distinguished a basal region (Rb), a hydrocladial region (Rh), and an intermediate region (Ri), the cauline joints of which bear hydrothecæ. The definitive stem (C) is characterized by the disappearance of cauline hydrothecæ. The joints of its inter-

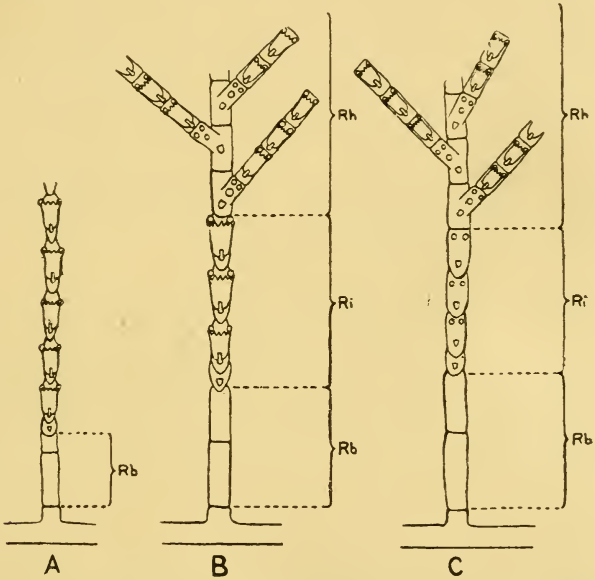


Diagram of three stages in the development of the stem of *Aglaophenia.*

mediate region bear nematothecæ only. The figure shows the typical architectonic scheme for a colony arising from a larva and not arising by budding from a hydrorhizal stolon. Modifications of the scheme may arise in various ways. J. A. T.

Variations of Aglaophenia pluma.—M. BEDOT (*Revue Suisse Zool.*, 1919, **27**, 243–82, 27 figs.). An interesting study of this Plumularid, showing the variations (or observed differences) in facies, size, hydrorhiza, stem, nematothecæ, hydrocladia, hydrothecæ, gonosomes, and so on. The species is re-defined on a broad basis of investigated form, three varieties are established, and the relation of *A. pluma* to related species is discussed. J. A. T.

Porifera.

Remarkable Phenomenon in Gemmule Cells of Fresh-water Sponge.—H. VAN TRIGT (*Arch. Néerland. Physiol.*, 1918, **2**, 594–603, 3 figs.). The turgescent cells of the gemmule of *Spongilla* are seen

before germination to expel drops of vitelline material. This prevents over-swelling of the cells, and it may also lead to cell-division by reducing the vitelline mass, for cell-division is slowed by the presence of much vitelline substance. J. A. T.

Protozoa.

Heredity and Variation in Arcella dentata.—R. W. Hegner (*Genetics*, 1919, **4**, 95–150, 26 figs.). The main problem attacked is, Can heritably diverse lines be recognized among the descendants of a single specimen of *Arcella dentata* multiplying vegetatively? It was found that a large family so derived consists of a number of branches that are hereditarily diverse with respect to diameter and number of spines. These diverse branches resemble the hereditarily diverse families that were obtained by vegetative reproduction from different "wild" specimens. The formation of such hereditarily diverse branches appears to be a true case of evolution that has been observed in the laboratory, and that occurs in a similar way in nature. J. A. T.

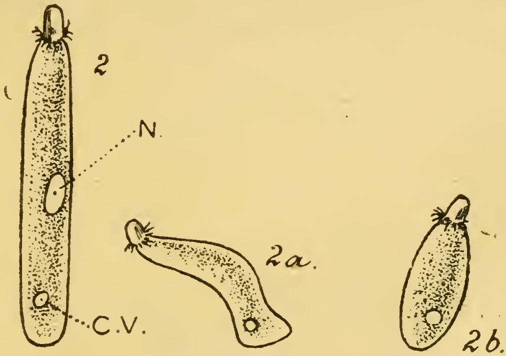
Culture of Amœbæ.—Monica Taylor (*Proc. R. Physical Soc. Edinburgh*, 1919, **20**, 179–82). Amœbæ were found flourishing in the more or less undisturbed mud with abundant organic débris in flowing water which secures good aeration. By adding wheat grains to the mud and by having sufficient water-weed to secure aeration, successful cultures were kept up in the laboratory throughout the winter. Plentiful food and good oxygenation seem to be the most important conditions. J. A. T.

Malarial Parasite in Blood of Buffalo.—A. L. Shearer (*Bull. Agric. Research Inst. Pusa*, 1919, **90**, 1–5, 2 pls.). The blood of an Indian buffalo showed small and large and dividing forms of what is probably a new species of *Plasmodium*, for which the name *bubalis* is proposed. J. A. T.

Toxicity of Acids to Ciliate Infusorians.—M. E. Collett (*Journ. Exper. Zool.*, 1919, **29**, 443–72, 6 graphs). The order of toxicity of a series of acids varies with the concentration, the temperature, and the species. The action is therefore not simple. The H-ion is an important factor, but not the only one. The anions of formic, acetic, propionic, butyric, valeric, citric, benzoic, phthalic, and salicylic acids are toxic to both *Paramecium* and *Euplotes*. The anions of oxalic, tartaric, lactic, and malonic acids are toxic to *Paramecium*, but not to *Euplotes*. The temperature co-efficients indicate that both chemical and physical reactions are probably concerned in the toxic effect of acids. A most marked irregularity is shown by acetic and butyric acids, in that their toxicity to *Euplotes* (though not to *Paramecium*) is greatly increased by temperatures below as well as above 20° C. J. A. T.

Ciliata of Lahore.—B. L. Bhatia (*Records Indian Museum*, 1916, **12**, 177–83, 3 figs.). Notes on *Paramecium caudatum*, with *three* con-

tractile vacuoles, as Bütschli observed in *P. putrinum* ; on *Holophrya indica* sp. n., which has a main posterior contractile vacuole, and a variable number (up to seven) of subsidiary vacuoles feeding it ; on *Lacrymaria vermicularis* (Ehrbg.), with a single circlet of reflexed cilia anteriorly, a single oval macronucleus, and a single contractile vacuole ;



Lachrymaria vermicularis (Ehrbg.).

2, fully extended ; 2*a*, moderately extended ; 2*b*, fully contracted. Full length 104 μ. N, macronucleus ; *c.v.*, contractile vacuole.

on a new subspecies of *Loxophyllum fasciola*, with contractile vacuole in two longitudinal rows ; and on other forms. J. A. T.

Ingestion of Erythrocytes by a Monad associated with Dysentery. —F. G. Haughwout and W. De Leon (*Philippine Journ. Sci.*, 1919, **14**, 207–19, 1 pl.). The Trichomonads found in the intestines of a man include members of three genera—*Trichomonas*, *Tetratrichomonas*, and *Pentatrichomonas*, with three, four, and five anterior flagella respectively. All are equiped with an axostyle and an undulating membrane bearing a marginal flagellum, which is continued beyond the posterior end of the body as a free lash. On the basis of present knowledge, the species of the first two genera seem to be lumen-dwelling forms subsisting solely on bacteria. But the authors have shown that *Pentatrichomonas* is adapted to the rather specialized diet of erythrocytes, and gives no evidence of being a bacteria eater. The actual process of the ingestion of an erythrocyte was observed; many individuals contained an erythrocyte ; in no case was expulsion seen. The inclusion of a red blood corpuscle in a *Pentatrichomonas* was reported by Chatterjee in 1915. J. A. T.

Fission in Trichomonads. — Charles A. Kofoid and Olive Swezy (*Proc. Amer. Acad. Arts and Sciences*, 1915, **51**, 289–364, 8 pls., 7 figs.). Mitosis and multiple fission occur during periods of great amœboid activity of the Trichomonads in the mucus of the intestinal epithelium. Mitosis is promitotic with the nuclear membrane intact

throughout the period of division, with nuclear separation by constriction, which simulates amitosis. It is, however, essentially mitotic, with extranuclear division centres, intranuclear spindle fibres, and chromosome organization out of a chromatin network and skein. The chromosomes are four in *Tetratrichomonas prowazeki*, five in *Trichomonas augusta*, *T. muris*, and *Eutrichomastix serpentis*. There is one small one and some fairly constant-size differences among the larger ones. They appear to be split longitudinally prior to their arrangement in the equa-

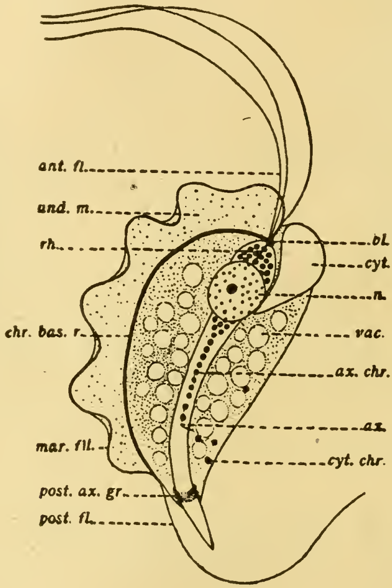


Diagram of *Trichomonas augusta*.

Ant. fl., anterior flagella; *ax.*, axostyle; *ax. chr.*, axostylar chromidia; *bl.*, blepharoplast; *chr. bas. r.*, chromatic basal rod or parabasal body; *cyt.*, cytostome; *cyt. chr.*, cytoplasmic chromidia; *mar. fil.*, marginal filament; *n.*, nucleus; *post. ax. gr.*, posterior axostylar granules; *post. fl.*, posterior flagellum; *rh.*, rhizoplast connecting blepharoplast and nucleus; *und. m.*, undulating membrane; *vac.*, food vacuole.

torial plate, and seem to slip into an end-to-end position in this plate, or to be parted by a transverse constriction.

The extranuclear organellæ all share in the mitosis. The blepharoplast—from which flagella, rhizoplast, chromatic margin and basal rod, and axostyle, all take their origin—contains the division centre. It parts into two bodies which go to the two poles of the fusiform mitotic nucleus, spinning out the deeply staining, always extranuclear, paradesmose between them. The daughter blepharoplasts may each divide in the polar position into an axial centrosome and an adjacent basal granule to which flagella, paradesmose, and parabasal are attached.

These two granules subsequently unite. In its divisions the blepharoplast shows no independent mitotic phenomena. It is not a "kinetonucleus," and its behaviour does not support the binuclearity hypothesis.

The anterior flagella are shared, two and one respectively, by the daughter blepharoplasts, and new outgrowths complete the complement of each daughter organism. The chromatic margin of the undulating membrane represents an intra-cytoplasmic posteriorly-directed flagellum. It splits longitudinally to the tip of its projecting end. The undulating membrane below it also splits. The chromatic basal rod is the homologue of the parabasal body of Janicki in *Parajœnia* and the Trichonymphidæ. His so-called parabasal in *Trichomonas* is in reality only the early stage of a new parabasal or chromatic basal rod at mitosis, hence its rarity and transitory nature. At mitosis a new parabasal or chromatic basal rod grows out in the base of one new undulating membrane, while the old parabasal lies in the other membrane.

The new axostyles of the daughter organisms are formed by the longitudinal splitting of the old. The axostyle is not for support or fixation ; it is a locomotor organ used vigorously in the amœboid phases. During mitosis the organellæ are shifted about a good deal. Plasmotomy is long delayed after nuclear mitosis. The plane of division is longitudinal. Multiple fission occurs as a normal phase of the life-cycle, and results in an eight-nucleate plasmodium or somatella. This disintegrates into its component members by the successive detachment of single merozoites. This multinueleate plasmodium may point on to Metazoa. J. A. T.

Chromosome Cycle in Gregarines.—A. PRINGLE JAMESON (*Quart. Journ. Micr. Sci.*, 1920, **64**, 207–66, 4 pls.). An account of the life-cycle of *Diplocystis schneideri*, a parasite of the cockroach, with special reference to the behaviour of the nuclei and chromosomes. The author deals with the life-history as a whole, the spore and the sporozoites, the penetration of the gut-wall and the growth of the parasite therein, the growth in the cavity of the body, the first nuclear division of the adult parasite (gamont), the later nuclear divisions, the peripheral divisions preceding gamete formation, the formation of the gametes, the union of the gametes, the first division (reduction division) of the sporoblast nucleus, the later divisions within the spore. A comparison is made between the nuclear phenomena in *Diplocystis* and those in other Gregarines. Special emphasis is laid on three points. 1. In *Diplocystis schneideri* a "micronucleus" makes its way inside a nucleolus, giving rise to a "karyosome" composed of two clearly differentiated portions. A similar construction of the karyosome occurs in many other Gregarines, and this raises the question how the entire Gregarine "nucleus" is to be compared with the nucleus of a Metazoan cell. It is probably a much more complex organ, comparable to a nucleus within a nucleus. 2. Hitherto, reduction in Gregarines has been sought for in the two nuclear divisions immediately preceding gamete formation. But in none of the so-called "reduction divisions" which have been described has a true reduction been demonstrated. In *Diplocystis schneideri* the reduction division has been found to be the first division in the

sporoblast, and this is probably the stage at which it occurs in other forms. This mode of reduction offers a simple explanation of the odd chromosome number which is so common in Gregarines; it is the haploid number which is present in every nucleus in the whole life-cycle except the zygote nucleus. 3. As Dobell has shown, it is futile to try to interpret the Protozoa in terms of the Metazoan cell. "Clarity of thinking will not come in Protozoology until the Protozoa are fully recognized as non-cellular organisms, comparable with whole Metazoan individuals rather than with their single component cells." J. A. T.

New Gregarines.—D. Keilin (*Parasitology*, 1920, **12**, 154–8, 1 pl., 2 figs.). Descriptions of *Allantocystis dasyhelei* g. et sp. n., from the midgut of the larva of a Ceratopogonid (*Dasyhelea obscura*), and of *Dendrorhynchus systeni* g. et sp. n., from the midgut of the larva of a Dolichopodid fly, a species of *Systenus*. In the first the two sporonts associated for reproduction do not change their form, but secrete a very long sausage-like cyst. The only other Gregarine where the sporonts do not contract before sporulation is *Ceratospora* from a Polychæt. In the second genus the epimerite has the form of a disc surrounded by numerous more or less ramified papillæ, which are fixed in an epithelial cell of the host's midgut. At various stages the cephalont, shedding off the epimerite, can separate itself from the host's epithelial cell and become a free moving sporont. Under the longitudinal striated epicyte there is a network of very well-defined circular fibrils with oblique anastomoses which surround the whole Gregarine. They correspond to myocyte fibrils. J. A. T.

New Coccidian.—Paul Debaisieux (*La Cellule*, 1914, **29**, 433–49, 1 pl.). A description of *Eimeria cystis-felleæ* sp. n. from the gall-bladder of the Grass Snake (*Tropidonotus natrix*). The formation of microgametes and of macrogametes, the schizogony and the sporogony are described. The life-history conforms to that already established for the genus. A comparison is made with the species *Coccidium agamæ* from an Agama and *C. cerastis* from a Horned Asp. The new species has cysts with perfectly hyaline membrane, and the spores are spherical or sub-spherical, both distinctive features. J. A. T.

Life-history of Ceratomyxa acadiensis sp. n.—James W. Mavor (*Proc. Amer. Acad. Arts and Science*, 1916, **51**, 551–74, 3 pls., 3 figs.). A new species of Ceratomyxa from the gall-bladder of *Urophycis chuss*, *Zoarces angularis* and *Pseudopleuronectes americanus*. The earliest stage contains a single nucleus. By a heteropolar division this single nucleus gives rise to a trophic and a propagative nucleus. The stage of the myxosporidium with four nuclei probably arises by the division of the trophic nucleus to form two tropho-nuclei, and the division of the propagative nucleus to form two propagative nuclei. The origin of the sporoblasts by the coming together of cells originally separate, as described by Awerinzew for *C. drepanopsettæ*, is confirmed for *C. acadiensis*. The presence of valve-cells and capsulogenous cells is noted. The two germ-nuclei can be distinguished in the early stages of spore-formation and until the spore is completely formed. J. A. T.

Parasitic Spiral Organism in Stomach of Cat.—R. K. S. Lim (*Parasitology*, 1920, **12**, 108–12, 1 pl.). Description of an extremely active organism, averaging 4 to 8 μ in length, with regular closely set spirals about $0 \cdot 75$ μ broad, found in the stomachs of eight cats, none of which showed any obvious signs of gastric disturbance. The organism occurred in the lumina of ducts and glands throughout the stomach, and also within the oxyntic cells. They were not seen elsewhere except at the very beginning of the duodenum. The organisms are new species of Spirochætoideæ. J. A. T.

Capillitia of Mycetozoa.—A. E. Hilton (*Journ. Quekett Micr. Club*, 1919, **14**, 1–8). There is great diversity in the nature of the capillitial threads associated with the masses of spores within the sporangia of Mycetozoa. The threads may be rigid or flexible, free or attached, solid or tubular, simple or branched, sparingly forked or forming a network, and so on. They have their origin in the processes, structural and metabolic, by which the plasm of an amœboid plasmodium is converted into the plasm of innumerable spores. The mode of development is described. "From first to last, the capillitial threads, notwithstanding their variety and often elaborate details, are sterile things, of only secondary importance, and of little biological significance." J. A. T.

BOTANY.

GENERAL,

Including the Anatomy and Physiology of Seed Plants.

Structure and Development.

Vegetative.

Embryo and Seedling of Dioon spinulosum.—H. A. Dorety (*Bot. Gaz.*, 1919, **67**, 251–6, 2 pls.). The material for this study was grown from ovules brought by Dr. Chamberlain from Mexico, where the plant forms a magnificent ornamental tree 30 to 40 feet high. The study of the vascular anatomy of embryo and seedling emphasizes the general harmony which prevails among the Cycads in this respect. The cotyledons vary in number from two to four, and are often lobed or divided;

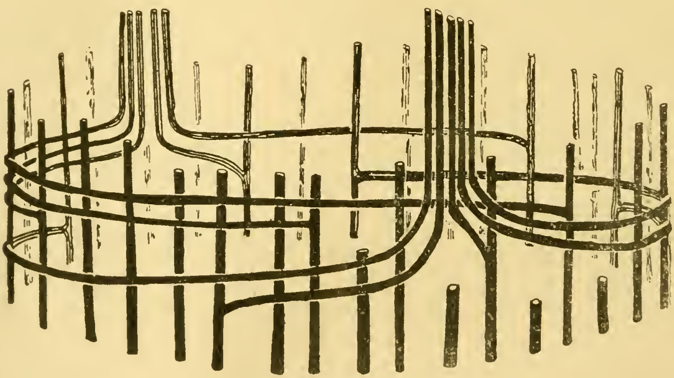


Diagram illustrating girdling of leaf-traces in stem.

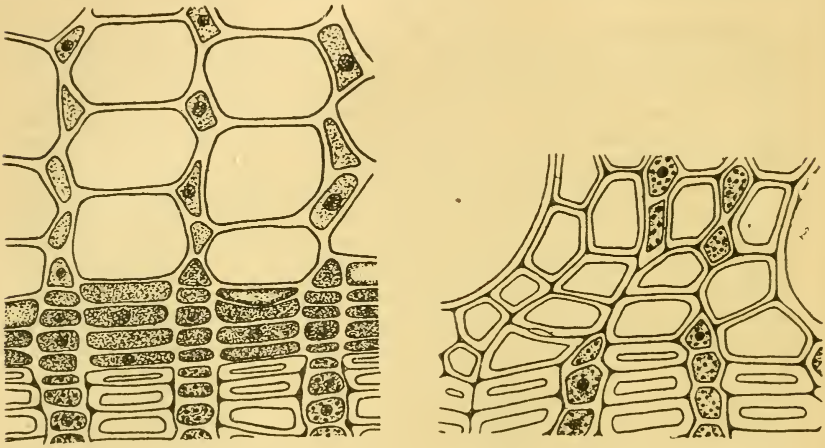
in rare cases the cotyledonary sheath is undivided except near the tip. They are multifascicular, resembling those of *Ceratozamia* and *Microcycas*, rather than those of *Zamia* and *Cycas*, which have but few strands. The arrangement and orientation of the vascular strands of cotyledons, hypocotyl, stem, leaves and root, do not differ in any marked degree from the general Cycad arrangement. The stem is large enough to demonstrate the cause of the girdling habit; each node of the stem is, like the nodes on a first-year stem of foxglove, telescoped within the older one instead of growing above it. The internodes are not elongated because the primary meristem of the stem-tip is held in check by

the more rapidly growing secondary meristem for each developing leaf. Since each leaf is supplied with strands from cauline bundles in different parts of the stem, those strands which come to it from the opposite side of the stem describe almost a semicircle to reach the leaf; those which arise on the same side of the leaf pass directly into it, and small arcs are described by strands which arise in intermediate positions. There is no extrafascicular cambium or any other vestige of polystely. A. B. R.

Polyxylic Stem of Cycas.—W. L. Miller (*Bot. Gaz.*, 1919, **68**, 208–21, 11 figs.). The author has studied the cambium of the stem of *Cycas media* in order to discover the origin and subsequent development, and to form some definite conclusions concerning the unusual method of secondary growth of the vascular elements. He has examined the xylem and phloem of the normal and first cortical cylinders of the full-grown stem, and finds that the vascular cylinders are of unequal length. The normal cylinder begins to differentiate at the meristem, while the others begin at successively lower joints; thus the normal cylinder is the only one which has its origin in the procambium, and which forms protoxylem and protoplasm. The protoxylem is usually scalariform, but elementary spiral tracheids are not infrequent. The primary xylem is also scalariform, while the secondary xylem is pitted. In the first cortical cylinder there is neither protoxylem nor protophloem; the xylem cells are mostly pitted, but a few scalariform tracheids are present. In the secondary phloem of both cylinders suberised bast-fibres are relatively numerous in comparison with the sieve-tubes. The origin and development are similar in all cortical cylinders, and their appearance is probably connected with the plant's periods of activity and rest. No material was available for studying the differentiation of cortical cambium. S. G.

Companion-Cells in Bast of Gnetum and Angiosperms.—W. P. Thompson (*Bot. Gaz.*, 1919, **68**, 451–9). In previous papers the author has indicated the existence in *Gnetum* of elements in the bast resembling the companion-cells of the angiosperms. The present is a comparative study of their structure and development. Companion-cells resembling those of angiosperms in size, in their association with sieve-tubes, in their usual location in the angles of the sieve-tubes, and in their vertical elongation, are present in the bast of some species of *Gnetum*. The development of these companion-cells, however, is quite different from that found in angiosperms. Whereas, in the latter, each sieve-tube and its companion-cell are derived from two successive cells in a single row of cambial products, in *Gnetum* sieve-tubes and companion-cells are produced from different rows of cambial cells. Thus although the completed forms of companion-cell in the two groups are similar, they have probably been independently evolved. Primitive conditions in which companion-cells are lacking, or in which continuous rows of companion-cells are present, are found in certain regions of some species. Thus they are absent in the young stem of *G. moluccense*, also in seedlings of several species and in reproductive axes. The parenchyma of the wood is formed by those cambial cells which form companion-cells;

the distribution of the wood parenchyma is consequently in radial bands, which frequently become interrupted by the expansion of vessels and fibres. The author has previously shown (*Bot. Gaz.*, 1918, **65**, 83–90), that in regard to the similarity of the wood-vessels with those of angiosperms, we are dealing with a case of parallel evolution and not of genetic relationship. If two such striking points of resemblance as



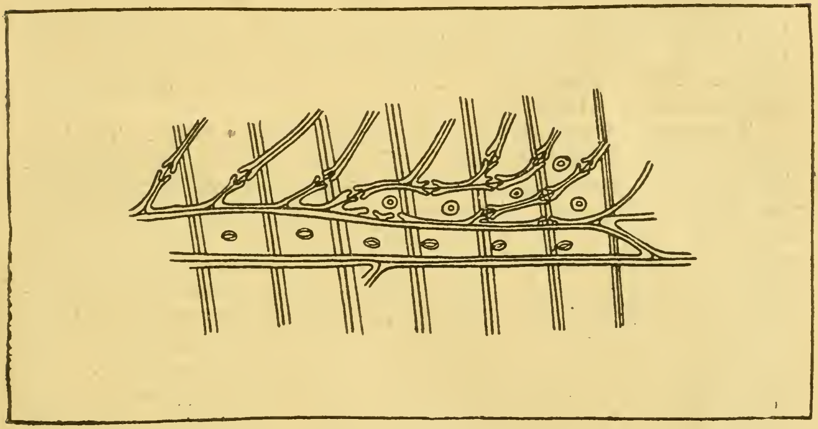
Wood, cambium and young bast of *Gnetum latifolium*, showing sieve-tubes and companion-cells formed from different rows of cambium cells; also wood-parenchyma formed inwardly from those cambial cells which form companion-cells.

vessels in the wood and companion-cells in the bast are the result of independent evolution in *Gnetum* and angiosperms, the inference is natural that other resemblances may be in the same category. A. B. R.

Hybrid Sarracenias and their Parents.—A. M. Russell (*Univ. Pennsyl. Philadelphia: Thesis*, 1919, 1–41, 5 pls.). The author has studied several species of *Sarracenia* in order to compare their macroscopic structures with those of their parents. The hybrid forms are intermediate in nearly every detail. Thus, the size of the hybrid is intermediate, although there is frequently increased vigour, a feature especially noted in hybrids of *S. Moorei* and *S. areolata.* The intermediate shape is best seen in *S. Catesbæi*, while other hybrids exhibit a distinct blending of both parents, especially in smaller details, such as the character of the lid. In colour intermediate blending is well shown, but with half the intensity of the colour of the parents. The flowers resemble those of both parents, but tend to be larger and more showy. All the above characters are readily visible to the naked eye, but the same intermediate features extend to the microscopic structures. The epidermal cells of the pitcher and the lid resemble those of both arents, and the number of stomata is an exact arithmetic mean of the

numbers found in the parents. The hairs found on both the pitcher and the rim likewise show a blending of the parental characters. Sections of the pitcher, the rim and the lid show that the cell-structure is intermediate in every respect. In all cases where there are apparent variations from exact blending, they are probably due to the higher state of evolution of one of the parents. The writer concludes that such overwhelming evidence of the blending of parental characters "points to some exact relation in molecular structure of the hybrid plant, extending even to the amount of thickening laid down in a cell-wall, the size of the starch-grains, or the size of a chloroplast." S. G.

Ray-tracheid Structure in Second Growth in Sequoia Washingtonia (S. gigantea).—H. C. BELYEA (*Bot. Gaz.*, 1919, **68**, 467–73, 5 figs.). Ray-tracheid structure is an essential feature of the Coniferales,



Radial section of second-growth wood, showing wood-tracheid bent and prolonged along the ray to act as ray-tracheid.

but is only constantly and normally present in the older genera. In the younger genera this structure may or may not be present, but is invariably recalled under traumatic stimulus. The author describes a peculiar adaptation in ray-tracheid structure in the second-growth wood tissue of *Sequoia gigantea*. Ray-tracheid structures have already been found to occur normally in both species of the genus, *S. gigantea* and *S. virens*. In the mature wood of the former two kinds are to be found—namely, single isolated detached radially elongated elements on the upper and lower margins of the primary rays; and, secondly, interspersed ray tracheids occurring in the radial prolongation of rays one cell high. In the present instance sections were taken from the main trunk of a tree which showed a phenomenally rapid growth. In this specimen true ray-tracheids do not occur, but the marginal structures on the rays of the wood of second growth show great variation. The vertical wood-tracheids terminate directly at the ray, and there are

communicating pits in the contiguous walls of the tracheids and the parenchyma-cells of the ray. There is also a radial elongation and projection of the ends of the vertical tracheary elements in a direction parallel to and in contact with the parenchymatous cells of the ray, with communicating pits in the intervening walls. As true ray-tracheids do not occur, it is believed that these structures are acting as such, and possess all the functions attributed to and carried on by ray-tracheids. In many cases the course of the bent and prolonged tracheid is imitated by those immediately contiguous with greater or less development. These structures are similar to those described by Thompson in the cone-axis of *Pinus Strobus*, and by Jones in the mature wood of *Sequoia sempervirens*. A. B. R.

Reproductive.

Staminate Strobilus of Taxus canadensis.—A. W. Dupler (*Bot. Gaz.*, 1919, **68**, 345–66, 3 pls., 22 figs.). In a previous paper (*Bot. Gaz.*, 1917, **64**) the author has described the gametophytes of this species. The development and vascular anatomy of the staminate structures are here treated.

The staminate strobili occur in the axils of the leaves. The buds may first be distinguished from other types of buds by the broad apex. The sporophyll primordia first appear as slightly rounded lobes above the general surface, and may arise in acropetal succession. The archesporial initials are hypodermal cells and develop according to the eusporangiate method. There are 4–8 of them, distributed around the margin of the primordium. The sporogenous tissue reaches the mother-cell stage about October 1, and forms microspores about two weeks later. There is no abortion of sporangia such as occurs in *Torreya*, the sporangia occurring in a circle around the stalk of the sporophyll. The sporangium-wall is usually two-layered. The tapetum arises from the peripheral layer of the sporogenous tissue and persists until after megaspore-formation. The epidermis of the sporangium remains alive and thin-walled at the base, dehiscence being accomplished by the rupture of these cells at maturity, by the elongation of the stalk of the sporophyll. Owing to the disintegration of the sporangium-wall, the epidermis is the functional wall in the later stages. The strobilus matures in the latter part of April. Just before maturity there is an enlargement and elongation of the axis, pushing the sporophylls beyond the scales. The strobili of *Taxus canadensis* are somewhat smaller than those of *T. baccata*. The strobilus-bundles are collateral endarch, excepting in the terminal portions of the scale-bundles and the sporophyll-bundles, where they may be mesarch, and in the latter show indications of occasional exarch structure, the terminal portion of these bundles also being concentric. A. B. R.

CRYPTOGAMS.

Pteridophyta.

Leaf-architecture as Illuminated by a Study of Pteridophyta.—F. O. Bower (*Trans. Roy. Soc. Edinb.*, 1916, **51**, 657–708, 1 pl. and figs.). There are three chief avenues which may lead up to a scientific knowledge of leaf-architecture. 1. A comparative study of adult leaves (mature or while developing) of many different types. 2. A study of the juvenile leaves of an individual, tracing the gradual stages up to the adult form; the results in various forms, related or otherwise, may then be made, especially those of more primitive types. 3. The results of such studies may be compared with the fossil record, and conclusions obtained as to phyletic progression. The second avenue has been somewhat neglected, especially in the Pteridophyta. In the present paper the juvenile leaves of this group are studied and compared with results obtained from other sources. A long summary of comparative conclusions is given, and a postscript on theories of the ultimate origin of the leaf. A. Gepp.

Maceration of Carboniferous Plant-remains.—K. Nagel (*Naturw. Wochenschr.*, 1917, **15**, 569–71, figs.; see also *Bot. Centralbl.*, 1917, **135**, 359). A popular account of the very important results of the recent experiments in macerating carboniferous impressions, in order to render possible a microscopical examination of the epidermis of prehistoric plants. By treatment with $KClO_3 + HNO_3$ (Schulze's maceration-mixture) the carboniferous plant-remains are reduced to a soft peaty condition, which, after treatment with ammonia (whereby the insoluble humus-acid produced during the oxidation is eliminated), allows the epidermis to be detached from the subjacent layers and to be studied in glycerin under the microscope. Some preparations of *Neuropteris ovata* Hoffm., *Anomozamites gracilis* Nath., and *Ctenopteris Wolfiana* Goth. are described. The method has been worked out recently by Zeiller and others, and has systematically yielded great results. A. G.

Old Red Sandstone Plants showing Structure, from the Rhynie Chert Bed, Aberdeenshire. Part I. Rhynia Gwynne-Vaughani Kidston and Lang.—R. Kidston and W. H. Lang (*Trans. Roy. Soc. Edinb.*, **51**, 1917, 761–84, 10 pls. and figs.). An account of a new genus of fossil plants summarized as follows:—*Rhynia Gwynne-Vaughani* grew in gregarious fashion in a peaty soil practically composed of the decaying remains of the same species. The land surface was probably in the neighbourhood of water, and liable to periodic inundations. The plant had no roots and no leaves. It was entirely composed of branched cylindrical stems. The branched underground rhizomes were attached to the peat by numerous rhizoids, most abundant on large, downwardly directed bulges of the outer cortex. Some of the branches grew upwards as tapering aerial stems. The aerial stems bore small lateral projections irregularly scattered over the surface. Some of the projections, possibly

in the lower regions, developed rhizoids. Some of the projections at various levels on the stem gave rise to adventitious lateral branches. Some of the lateral branches, attached by a narrow base, were readily detachable and probably served for vegetative propagation. Dichotomous branching of the stem occurred sparingly. In the rhizomes and stems, epidermis, outer cortex, inner cortex, and stele can be distinguished. The epidermis in the aerial stems had a thick outer wall, and stomata were sparingly present. The cortex consisted of a narrow outer zone, which in the aerial stems had the character of a hypoderma, and a broader inner cortex. The more delicate tissue of the inner cortex had intercellular spaces and was in relation with the stomata. It possibly represented the assimilating tissue. The vascular system consisted throughout of a simple cylindrical stele composed of a slender solid strand of tracheids with broad annular thickenings and no distinction of protoxylem and metaxylem. Surrounding the xylem was a zone of phloem consisting of elongated thin-walled elements. No vascular strands were given off to the small projections on the stem. No vascular connexion existed between the stele of a lateral branch and the stele of the parent axis. In the dichotomous branching of the stem the stele divided to supply the two branches. The branch bore large cylindrical sporangia. The sporangium had a thick wall, and terminated a stout stalk which corresponded to a small stem. The sporangium contained numerous spores which were all of one kind. The authors find the plant to be allied to *Psilophyton princeps* Dawson, and place them in a new class, Psilophytales. A. G.

Contributions to our Knowledge of British Palæozoic Plants. Part I., Fossil Plants from the Scottish Coal Measures.—R. KIDSTON (*Trans. Roy. Soc. Edinb.*, 1916, **51**, 709–20, 3 pls. and figs.). Descriptions and figures of the fossil species—*Sphenopteris incurva* (new), *Sphenophyllum cuneifolium*, *Sigillaria elegans*, *S. incerta* (new), *S. Strivelensis* (new), *Stigmaria minuta*, *Lagenospermum parvulum* (new).
A. G.

Anatomy and Affinity of Platyzoma microphyllum R. Br.—JOHN MCLEAN THOMPSON (*Trans. Roy. Soc. Edinb.*, 1916, **51**, 631–56, 4 pls. and figs.). An account of the structure of this tropical Australian fern, which is notable for the heterophyllous character of its xerophytic foliage. On the horizontal rhizome, zones of reduced leaves usually devoid of pinnæ alternate with zones of larger pinnate fertile leaves. Bifurcate leaves sometimes occur. *Platyzoma* has always been placed in the Gleicheniaceæ, but differs markedly in the crowding of its leaves, as well as in the remarkable characters of its stele, leaf-trace and sporangia. The *stele* is protostelic, a continuous ring without leaf-gaps; the xylem is in two zones, the inner a storage zone; the bulky pith is sclerotic and mucilaginous, and is surrounded by a continuous inner, distinct from the outer, endodermis; outside the xylem is a narrow zone of phloem, a pericycle, and external endodermis. The *leaf-traces* issue (without leaf-gap) from the outer xylem as a crescentic mass of tracheids with an outer arc of phloem; the further development of the leaf-trace and the behaviour of the endodermis are described. The *sporangia* do

not constitute definite sori, but are distributed solitarily, terminally on the veins; there is no indusium, but hairs occur along the veins and revolute margins of the pinnæ. The sporangium is short-stalked, globular, with oblique irregular annulus, interrupted at the stalk; the stomium is variable. The larger sporangia contain 12–16 large spores; the smaller, 26–32 small spores. *Platyzoma* has no close affinity with Gleicheniaceæ, though probably of common origin. A. G.

Anatomy and Affinity of Deparia Moorei Hook.—JOHN McLEAN THOMPSON (*Trans. Roy. Soc. Edinb.*, 1915, **50**, 837–56, 3 pls. and figs.). An account of the structure of the sporophyte of this fern, and a discussion of the significance of the anatomy of its members. The phyletic and systematic position are debated at some length, and the conclusion is reached that the morphological characters described in the paper show *Deparia Moorei* to stand high in the scale of ferns, and indicate for it a Davallioid affinity. A. G.

Anatomy and Affinity of certain Rare and Primitive Ferns.—JOHN McLEAN THOMPSON (*Trans. Roy. Soc. Edinb.*, 1918, **52**, 363–97, 7 pls. and figs.). An account of *Jamesonia*, *Llavea* and *Trismeria*. Their structure is described; and they are compared with *Gymnogramme*, *Cryptogramme*, *Cheilanthes*, *Nothochlæna*, *Pellæa*, *Ceratopteris* and *Plagiogyria*. The anatomical and sporangial characters are held to indicate for *Jamesonia* an ultimate origin from some Schizæaceous source; the same applies to *Llavea*, which is more advanced than *Jamesonia*; and as to *Trismeria*, the conclusion is that it is not a distinct genus, but an "Acrostichoid" *Gymnogramme*. A. G.

Some Notes on Neurosoria pteroides (R. Br.) Mett.—W. WALTER WATTS (*Journ. Proc. Roy. Soc. N. S. Wales*, 1919, **53**, 49–57, 2 pls.). This fern, originally named *Acrostichum pteroides* by Robert Brown, was assigned to *Phorolobus* by Desvaux, by Mettenius to *Neurosoria* n. g., by Moore to *Gymnopteris* or to *Cheilanthus*, by Kuhn first to *Allosorus* and later to *Neurosoria*, which genus Kuhn described at some length in 1869. Watts now criticises Kuhn's description and conclusions, and decides that *Neurosoria* should be placed in the Cheilanthinæ, falling into the group with thickened nerve-ends, but with the sori occupying the whole of the upper nerve-branches, while in *Cheilanthes* and *Hypolepis* the sori are confined to the nerve-ends, being more or less confluent in *Cheilanthes*, and solitary at the base of a leaf-sinus in *Hypolepis*. A. G.

Prothallus of Tmesipteris tannensis.—A. ANSTRUTHER LAWSON (*Trans. Roy. Soc. Edinb.*, 1917, **51**, 785–94, 3 pls.). An account of the discovery of the prothallus of *Tmesipteris* in New South Wales, and of its structure. It is small, subterranean, saprophytic, characterized by numerous long rhizoids, is light brown in colour (hence inconspicuous in its habitat), without chlorophyll, associated symbiotically with a mycorrhizal fungus. The antheridia are large and scattered, the archegonia quite small and numerous; and these organs do not much resemble those of *Equisetum* or *Lycopodium*. The description of the

embryo is postponed until better material is available. The suggestion of both Bower and Scott that *Psilotum* and *Tmesipteris* find their affinity among the ancient Sphenophyllales is strengthened by the facts in the present paper. A. G.

Pteridophyta of Indo-China.—PRINCE N. BONAPARTE (*Notes Ptéridologiques*, Paris, 1919, Fasc. **8**, 197 pp.). The present fascicle contains the first part of a monograph of the ferns of Indo-China, i.e. Siam, Lagos, Tonkin, Cambodia, Annam and Cochin-China, and comprises the first four families — Hymenophyllaceæ, Gleicheniaceæ, Schizæaceæ, Cyatheaceæ. Descriptions, sometimes original, are given for each family, genus and species ; and keys are provided. The synonyms and illustrations of the species are given, and their geographical distribution, and critical remarks where necessary. A. G.

Bryophyta.

Ramification of Mosses : A Morphological Study.—K. KAVINA (*Hedwigia*, 1915, **56**, 308–32 ; see also *Bot. Centralbl.*, 1918, **137**, 75–6). The mode of branching in mosses is monopodial, in Sphagna dichotomous, and in liverworts more often dichotomous than monopodial. These three groups form three independent parallel types, which probably have nothing but their origin in common. The following details are of special interest :—A pushing up of the subtending leaf on to the daughter-axis in *Calliergon cuspidatum* and *Antitrichia curtipendula*. Regular axillary branching is the most usual, in which the branch stands exactly in the median line of the leaf-axil (e.g. *Eurhynchium murale*, species of *Philonotis*, *Hylocomium loreum*). In *Mnium* no sort of branch sheath is present. It is represented only by the knob-like swelling of the basal part of the axillary branch. Sometimes it is found that the lateral shoot does not appear to be so exactly lateral as it should be, but stands high above the axis of the subtending leaf, either precisely in the median line or to the right or left of it ; in both cases apparently breaking the general rule of monopodial branching. The explanation is that in the first case the lateral shoot grows together with the main axis for a certain distance, or there occurs a displacement of the lateral shoot high above the leaf-axil (*Rhytidiadelphus triquetrus*, *Calliergon stramineum* ; in the second case a torsion of the main stem takes place (*Hedwigia*, *Climacium*), or plagiotropism has been the influence (*Eurhynchium* sp. *Leskea* sp. *Neckera* sp.) Adventive shoots have no orientation to the leaves. The subject of orientation is discussed : dorsiventral, opposite, and transverse. But it is so variable that it is impossible to set up any types. The " first leaves " are, according to the author, of a trichome-like nature ; only in *Mnium* divided normal leaves occur in the form of bristles. The small scale-like or bristle-like leaves occurring between the normal leaves in the middle of the lateral shoots or on the adjacent stems in *Mnium*, *Hypnum*, *Climacium*, *Scleropodium*, etc., are trichomes, and only requisite for their biological function—namely, the enveloping of the young vegetative growing point. E. S. GEPP.

Studies on the Biology and Geography of Mosses. I. Biology and Ecology of Mosses.—C. GREBE (*Hedwigia*, 1917, **59**, 1–205; see also *Bot. Centralbl.*, 1918, **137**, 87). This may be called a handbook of practical biology and ecology of mosses, and is the result of very numerous observations made by the author during long decades. He has studied the mosses of all the mountainous districts of Central Germany *in situ*, as has never been done previously; and while he contents himself principally with recording his actual observations, he follows the teleological methods of thought when he seeks to explain them. The work contains the following sections:—(1) Humicolous, Humus-fed, and Saprophyte. (2) The biology of water- and swamp-mosses. (3) The xerophytic structure of the xerophilous mosses. (4) Behaviour of mosses towards light and shade. (5) Moss vegetation of woodland formations. (6) Calcicolous mosses and their behaviour to the substratum. (7) Fresh mineral soil and its influences. (8) Biology of the inflorescence. (9) The peristome of mosses and its functions. (10) Appropriateness in organic structure in mosses. Each section is further sub-divided, and the subjects discussed from all sides. E. S. G.

Bryological Novelties.—C. WARNSTORF (*Bryol. Zeitschr.*, 1916, **1**, 33; see also *Bot. Centralbl.*, 1918, **137**, 108). The result of a series of small investigations of the structure and systematic position of certain Bryophytes. *Pleuroclada albescens* is compared with *P. islandica*, and the latter is proved to be merely a delicate habitat-form, having small, widely separated leaves. In *Mnium affine* an abnormal leaf formation, with very strong, forked midrib, is described. Vegetative propagation has been observed in *Sphagnum molluscum*; a lateral shoot having stem characters with leafy branchlets was found in the place of the usual branch tuft; and on normal stems there occur single long subcomal shoots; also there occurred, on an otherwise normal stem of *S. amblyphyllum*, a stem-like lateral shoot arising from the base of a branch-tuft, and bearing a small terminal head and slightly developed leaves. *Fontinalis antipyretica* var. *mollissima* is described, and support is given to the view that *F. arvernica* is a variety of *F. antipyretica*; as also *F. fasciculata* Lindb. var. *danubica* Cardot, from the bank of the Danube at Neustadt, and *F. Lachenaudi* Cardot. On the other hand, var. *laxa* of *F. antipyretica* is regarded as worthy of specific rank. A hermaphrodite flower is recorded for *Pohlia nutans*, hitherto known as protogynous. Finally, nematode colonies are described in *Grimmia montana*. E. S. G.

Scapania paludicola Lœske et C. Müll.: Contributions to the Question of Parallel Forms in Mosses.—L. LOESKE (*Ungar. bot. Blätter*, 1915, 298–302; see also *Bot. Centralbl.*, 1918, **137**, 135, 136). A detailed discussion of the two species of *Scapania*, which are united under *S. paludosa* C. Müll.—namely, *S. undulata-paludosa* and *S. irrigua-paludosa*. Both are alike in inhabiting swamps at high altitude, in their lax growth, their pale green colour, and in having a short, remarkable arcuately curved commissure. The different species are distinguished without difficulty by their areolation. In

S. undulata, the leaf-cells are either thin-walled or of even thickness throughout; in *S. irrigua* the cells have triangular thickenings. These differences in areolation are hereditary (phyletic). *S. paludosa* C. M. is here regarded as an extreme and striking swamp-form of the very variable *S. undulata*, forming perhaps the opposite pole in *S. dentata*, which is the other extreme of *S. undulata*, *S. dentata* occurring in the Upper Harz mountains, and being regarded as a xeromorphosis of *S. undulata*. In herbaria the two species distinguished above lie side by side under *S. paludosa*. Since the name was created for the former of the two, the name of *S. paludicola* Loeske et C. Müll. is created for the latter. A considerable portion of the northern *Martinellia paludosa* belongs to *S. paludicola*. Two conditions help to bring about such parallels: the respective original species must be closely allied (as is the case here), and demand similar conditions. But they must be also very variable and extremely open to influence by the action of water. In the case of *Philonotis* the action of water brings about variation along similar lines to so great an extent that it is sometimes only possible to guess the species, not to determine it with certainty.

E. S. G.

Organic Balancing between the Pedicel of the Female Receptacle and that of the Sporogonium in Lunularia vulgaris.—P. Lesage (*Comptes Rendus Acad. Sci. Paris*, **160**, 1915, 679–881). The author obstructed the upward growth of the pedicels of the female receptacles in the species by covering them down with bricks; and found the pedicels of the sporogonia to become longer than normal. He concludes that in this a compensation may be discerned. A. G.

Liverworts of Germany, Austria and Switzerland, with Consideration of the other European Countries.—K. Müller (*Rabenhorst's Kryptogamen-flora, Leipzig*: E. Kummer, 1916, **6**, Lief. 28, 849–947). The final part of this monograph. A chapter is devoted to Vertical Distribution of the Liverworts, and another to their Ecology. The dependence of Liverworts on climatic factors (warmth, light, moisture) and on biotic and edaphic factors is discussed. A complete index of families, genera, species, varieties and forms, with all synonyms, completes this work, the preparation for which has taken eleven years.

E. S. G.

Thallophyta.

Algæ.

Thalassiophyta and the Subaerial Transmigration.—A. H. Church (*Botanical Memoirs, No.* 3, *Oxford University Press*, 1919, 95 pp.) An essay on the origin of the Land Flora. The author shows that the latter must have been derived from the marine algæ, and indeed from green algæ of the highest type of development. Life originated in the sea from the ionized sea-water, yielding unicellular plankton organisms, autotrophic chiefly, but associated with their animal derivatives. To this plankton phase was added after vast ages a benthic phase, when the sea-bottom, slowly elevated to within 100 fathoms from the surface,

afforded a safe anchorage to algæ (and animals), which then began to develop a multicellular structure and to elaborate modes of reproduction and of spore-dispersal necessitated by their sedentary existence. After further ages the sea-bottom gradually came right to the surface, and the exposed algæ and animals had to adapt themselves to aerial conditions or to perish. Several of the best fitted successfully passed through the ordeal, but in the struggle became so drastically altered in shape, structure, physiology and modes of reproduction that the ancestry of the distinct phyla of the Bryophyta, Lycopods, Equisetaceæ, Ferns, Gymnosperms, Angiosperms, etc., is now untraceable, though in several of them an ancient and primitive character survives in the structure of the respective antherozoids, and affords powerful evidence as to ancestral affinities. Another interesting group are the Fungi. These date from the same period of land-emergence, and had a markedly polyphyletic origin (e.g. Phycomycetes, Ascomycetes, Basidiomycetes, Uredineæ); they too came through great tribulation in adapting themselves to a saprophytic or parasitic life and in elaborating resting-spores, air-borne spores, etc., which enabled them to withstand drought and secure a wide dispersal. No trace of the highly organized green algæ of the transmigration is to be found in geological strata. They became land-plants, or they perished. But the brown and the red algæ were not fitted for the transmigration, being inadequately developed in reproductive mechanism (brown algæ) or in vegetative structure (red algæ).

The memoir is of the highest importance in connexion with the study of the fundamental facts of botany, and is replete with details, deductions and arguments which can only be studied with advantage in the original text. A. G.

Terminology of Alternation of Generations in Plants.—D. Renner (*Biol. Centralbl.*, 1916, **36**, 337–74; see also *Bot. Centralbl.*, 1918, **137**, 97–8). An attempt to bring uniformity into the terminology of alternation of generations. The author disapproves of the term in the Hofmeister sense, and seeks to prove among the most varied families of the plant world that where alternation of phases is present, alternation of generations does not necessarily exist also. "Alternation of generations" he acknowledges exclusively in those cases "where, over and above the zygote, at least a second obligate germ-cell, a true spore, is present, which does not originate directly at the germination of the zygote." Under "generation" he understands a portion of the development which is intercalated between two different obligate germ-cells, and to a certain extent exhibits vegetative growth. Alternation of phases would then be an alternation of stages having haploid and diploid nuclei and need not necessarily coincide with alternation of generations. Thus *Spirogyra*, which completes its reduction-division on the germination of the zygote, lacks, according to the author, an alternation of generations. The author's view is that the gametophyte begins with the gonospore, or in some cases with the gonotokont and ends with the gametes, while the sporophyte represents a generation which produces spores. The gametophyte is always haploid, while the newly defined sporophyte is as a rule diploid; but in those cases where

it arises from a zygote which may also be haploid (e.g. *Scinaia*, in which reduction-division is completed directly on germination) the gonimoblast is haploid. Different cases are to be distinguished according to whether the diploid sporophyte produces gonospores (mostly similar to tetraspores) or tokospores (a new and degenerate expression coined by the author for gonotokont-spores), or diplospores. These views are also applied to the various families of plants. E. S. Gepp.

Periodicity and Geographical Distribution of the Algæ of Baden.—A. Rabanus (*Ber. Naturforsch. Freiburg i. Br.*, 1915, **21**, 1–158; see also *Bot. Centralbl.*, 1917, **135**, 389–91). The work has a double aim: to give an insight into the periodicity of the algæ during the course of a year in various localities, and to give a geographical account of the algæ of Baden. A résumé of previous work on the subject is followed by an account of the algal vegetation of the Black Forest, the plain of the Rhine and the Kaiserstuhl. The difference in the flora of the three regions arises from the differences of temperature and the varying water-level. After describing the annual cycle of algæ in the various habitats, the author discusses their periodicity in different localities—the ditches by the roadside in the plains, the mountainous districts, rivers, ponds, marshes, etc. Most of the species are too much (*Ulothrix*) or too little (*Cylindrocystis*) dependent on outside factors to allow of an inherited periodicity in their life-cycle. Only *Spirogyra* flourishes from autumn to spring, or only in the spring, and mostly in puddles and ditches which are filled with water only in the rainy season. The explanation of "water bloom" is still far to seek. Certain algæ retained life through a prolonged period of freezing, and this is dependent not only on the degree of the frost, but on the "mood" of the algal cell. The resistance to heat varied greatly, the most sensitive being *Ulothrix*, in lesser degree *Stigeoclonium* and *Conferva*; *Vaucheria* can bear fairly high temperatures. Many other interesting peculiarities are noted for various species. The geographical distribution is fully treated. A list of species recorded for Baden is given, and certain aberrant forms of Desmidiaceæ are described, but not named. Various results are shown in tabular form. E. S. G.

Notes on Some Intermediate Forms of the Genera Navicula and Cymbella.—Sir Nicholas Yermoloff (*Journ. Quekett Microsc. Club*, 1918, **13**, 18 pp., 3 pls.). The author shows by a process of "synthetic integration" that the fossil diatom *Navicula monmouthiana* may be considered as an ancestral form of a whole series of species of *Cymbella*, which he describes. The series ends in the very small *C. microcephala*, the intermediate forms passing almost imperceptibly from one to the other along the ladder. It is presumed that the parental fossil form *N. monmouthiana* appeared about the end of the Pliocene period in the State of Maine, and the descendant species have been evolved during the subsequent Quaternary period up to the present day. As regards the term "species," the author gives a definition which was advocated in Russian scientific circles before the war: "A species in Nature corresponds to what in the Differential Calculus is

meant by a derived function; it is a certain type-limit, to which tend, without even sometimes quite identically attaining it, certain varying intermediate forms." He enumerates seven distinguishing features in the systematic classification of diatoms, and advocates a close comparison of fossil and living forms for determining the lines of genealogical descent. Certain observations are made on the structure of the genus *Cymbella*, and of the various intermediate forms lying between *N. monmouthiana* and *C. microcephala*. The tendency in some of the intermediate forms to triundulate margins may perhaps be regarded as a transitional rather than as a specific character. Descriptions of the various recognized species are given, and the various changes along the road of transition are pointed out. E. S. G.

Amphora inflexa, a Rare British Diatom.—G. WEST (*Journ. Quek. Micr. Club*, 1919, **14**, 6 pp. 1 pl.). An authoritative reply to the various doubts and queries concerning the identity of a species of diatom collected by Capt. D. Griffiths in Carmarthen Bay in 1915. *Amphora inflexa* has been published under various synonyms. It has been recorded from Calvados and Biarritz in France, and from the Adriatic; in England from Ilfracombe and the Tay, previous to Capt. Griffiths' find in Wales. In the present paper the differences between this species and the various genera in which it has been placed are pointed out, and the species itself is for the first time adequately described and figured. It is a free marine diatom, living amongst the muddy sediment in rock pools within tidal influence. *Navicula scopulorum* Bréb., *N.* (*Schizonema*) *ramosissima* Ag. and *Toxonidia insignis* Donk. were found in the same gathering as *Amphora inflexa* (Bréb.) H. L. Smith. E. S. G.

Action of Sulphate of Copper on Plankton.—A. BÉTANT (*C. R. Soc. Phys. d'Hist. Nat. Genève*, 1918, **35**, 86–91). A successful attempt to eliminiate plankton from the drinking water taken from the Lake of Geneva by the action of sulphate of copper. The annual report of the Water Board shows a fairly even quantitative distribution throughout the years, with the exception of May to July, when a very variable increase may take place. In 1914 and 1917 it did not exceed 380 and 500 $mm.^3$ per 100 litres of water, while in 1915 it reached 5273 $mm.^3$, and in 1918, 3100 $mm.^3$ per 100 litres. During the rest of the year the proportion is fairly constant at 100 $mm.^3$. Among the diatoms the characteristic species are: *Fragilaria crotonensis*, *Cyclotella*, *Synedra*, and others less frequently; among green algæ, *Spirogyra*, *Sphærocystis*, etc. The method of killing the organisms with sulphate of copper and letting them sink down and form a sediment is fully described, and was attended with perfect success. While the natural water before treatment contained 150 $mm.^3$ of plankton, it showed only 7 $mm.^3$ per 100 litres afterwards. E. S. G.

Synopsis of the Biological Examination of Water.—J. WILHELMI (*Sitzungsber. Ges. naturf. Freunde Berlin*, 1916, **9**, 297–306; see also *Bot. Centralbl.*, 1917, **135**, 191–92.) A criticism of the Kolkwitz-Marsson scheme for the grouping of the biological contents of water,

and the presentation of a new scheme. The author regards as necessary the determination, quantitatively and qualitatively, of the organic and inorganic floating matter, Plankton and Tripton. He distinguishes three groups: I. Euplankton (Kolkwitz) and Eutripton. In size the two are analogous. Both are found in the clearest water as Nannoplankton and Nannotripton. II. Pseudoplankton and Pseudotripton. Under the former he understands all organisms which may live in water but do not actually find therein the true conditions essential to life; such as organisms torn from the bank or the bottom and able to exist for a certain time, or those attached to Euplankton individuals, or those dependent on sewage (Saproplankton). III. Hemiplankton and Periplankton. All organisms which pass a certain stage of their development as a plankton unit. The auto-purification of sewage is more difficult to bring about in the sea than in fresh-water. Impurities of harbours and of bays in tideless seas cause an enormous development of *Ulva Lactuca* through a rich supply of nitrogen, and it fouls the water and spreads disease. E. S. G.

Fresh-water Biological Institute at Aneboda, and the Scientific Investigations carried out there.—E. Naumann (*Skrift. Södra Sver. Fiskeriför. Lund*, 1916, No. 13, 17 pp.; see also *Bot. Centralbl.*, 1918, **137**, 134–5). In connexion with the Swedish Fishery Association a laboratory was opened at Aneboda in 1907, for the investigation of problems of fresh-water biology and fishery. The influence of the food supply on planktological conditions of the water was examined. It was shown to produce a more or less marked change of the chemical medium, and in a mildly saprobilizing direction, which caused an increase in certain plankton forms, often in extreme degree. These culture formations have a two-fold importance. They bring about a normal biochemical automatic regulation of the water—a sort of automatic protection against otherwise harmful remains of nutrition; and the increased production of phyto-plankton provides a larger supply of food for the pelagic and benthic fauna. E. S. G.

Simple arrangement for obtaining Biological Samples of Water from the deeper Water Strata.—E. Naumann (*Skrift. Södra Sver. Fiskeriför. Lund*, 1916, No. 13, 8 pp.; see also *Bot. Centralbl.*, 1918, **137**, 135). A description of a new type of dipping-bottle used by the author for some years for biological purposes. The appearance of the apparatus is described and figured. It is specially adapted for the collection of quantitative samples of water from various depths.

E. S. G.

Lietzensee, near Berlin: An example of Applied Hydrobiology.—E. Naumann (*Skrift. Södra Sver. Fiskeriför. Lund*, 1916, No. 13, 34 pp.; see also *Bot. Centralbl.*, 1918, **137**, 135). An exhaustive report on the investigations of R. Kolkwitz on the plankton production of the Lietzensee, together with a discussion of the measures undertaken by him for the reduction of the surplus production. An original drawing is given of *Oscillatoria Agardhii* Gom. E. S. G.

Marine Algæ of the Pacific Coast of North America. Part I.: Myxophyceæ.—W. A. Setchell and N. L. Gardner (*University of California Publications*: *Botany*, 1919, **8**, 1–138, 8 pl.). This is the first part of a complete account of the seaweeds of the Pacific Coast; and the three remaining parts are stated to be in advanced preparation. The present one contains thirty genera of Blue-green Algæ, under which are placed ninety-six species and some varieties and forms. Descriptions of the orders, families, genera and species are given, and are amplified with critical notes. The addition of keys facilitates the naming of specimens. A marine flora of this region has long been needed. A. G.

Preliminary Catalogue of the Pelagic Flora of the Bay of Quarto dei Mille, near Genoa.—A. Forti (*Nuova Notarisia*, 1920, **31**, 65–72). Merely a preliminary list of 235 species collected in the Bay during the whole year of 1915 by Raffaele Issel, to be followed by full details and descriptions later; a study carried out at the Marine Laboratory of Quarto dei Mille. The recorded species include 1 Cystoflagellate (*Noctiluca miliaris* Sur.), 123 Peridiniales, 101 Bacillariales, 3 Silicoflagellata, *Coccolithophora leptopora* Lehm., and 6 Chlorophyceæ. E. S. G.

Parasitic Floridæ: I.—W. A. Setchell (*Univ. California Publ. Bot.*, 1914, **6**, 1–34, 6 pls.). A monograph of the genus *Janczewskia*. After a short introduction the author gives a history of the genus, followed by a short account of his materials and the host plants. The morphology of *J. verrucæformis* and *J. tasmanica* is then discussed as representing the extremes of structure thus far discovered in the genus. All three sorts of reproductive bodies usually found among Florideæ are known in this genus. Under taxonomy a critical description is given of each of the six species, of which four are new. The host-plant of one of them, *J. Solmsii*, is the species commonly known as *Laurencia virgata*, but has proved to be (either wholly or in part) *Chondriopsis subopposita* J. Ag., a true species of *Laurencia*. *Janczewskia* is divided into two groups which differ in certain morphological details. The genus is widely distributed in temperate seas from the Mediterranean to the Cape of Good Hope. Since their hosts, Laurencieæ and Chondrieæ are also abundant in the warmer temperate and tropical waters, the parasite may reasonably be supposed to have a wider distribution than is at present known, since they both belong to the same family. The paper is well illustrated. E. S. G.

Marine Algæ of the Danish West Indies.—F. Börgesen (*Dansk Bot. Arkiv.*, 1919, **3**, 305–68). A further continuation of this work. The present part completes Rhodomeleæ, including Delesseriaceæ and Bonnemaisoniaceæ, and begins the treatment of Gigartinales, family Gigartinaceæ. Each species is fully discussed and nearly all are figured in habit and structure, as in previous parts of the work. The novelties described are *Cottoniella arcuata* g. et sp. n., *Dasya caraibica*, and a var. *laxa* for *Heterosiphonia Wurdemanni* Falkenb. E. S. G.

Additions to "Oceanic Algology."—A. Mazza (*Nuova Notarisia*, 1920, **31**, 1–64). Additional species of genera and further notes on species already treated in the main body of this work. In the present contribution the note on *Porphyroglossum Zöllingeri* Kütz. is completed, and is followed by a discussion of *Acanthopeltis japonica* Okam., *Hennedya crispa* Harv., *Iridæa*, *Besa papillæformis* Setchell, and a number of species and forms of *Gigartina.* The notes on structure, nomenclature, etc., are full of detail. E. S. G.

Tertiary Calcareous Algæ from the Islands of St. Bartholomew, Antigua and Anguilla.—M. A. Howe (*Carnegie Inst. Washington*, Publ. 291, 1919, 9–19). Descriptions and illustrations of the fossil calcareous algæ collected in February and March 1914 by Dr. T. W. Vaughan, in the Eocene limestone of St. Bartholomew, the middle Oligocene formation of Antigua, and the upper Oligocene of Anguilla. The new species are described in detail and compared with already known species. They belong to the genera *Archæolithothamnium*, *Lithothamnium*, *Lithophyllum*, and *Lithoporella.* E. S. G.

Melobesieæ of the Danish Antilles Collected by Dr. F. Boergesen.—Madame Paul Lemoine (*Bull. Mus. d'Hist. Nat.*, 1917, 133–6). Notes on the geographical distribution of the Melobesieæ founded on collections made by Dr. Boergesen and those in the Museum of Natural History in Paris. The calcareous algæ of the Danish Antilles is limited to four genera, *Lithothamnium* (4 sp.), *Lithophyllum* (9 sp.), *Porolithon* (3 sp.), and *Melobesia* (4 sp.), and nearly all are crustaceous forms. Conditions are apparently unfavourable for branched forms. The distribution throughout the Antilles is fairly uniform, and a certain number of species occur also in Florida, the Bahamas and Bermuda. There appears to be no analogy between the species north and south of the equator, two or three only being common to the Antilles and Brazil. Except the ubiquitous *Melobesia farinosa* there is no species in common between the Antilles and the Atlantic Coasts of Europe, though two of the former have been recorded from Cape de Verde and in the Gulf of Guinea. Certain Antilles species show close affinity with certain tropical Pacific species from Borneo, Sumatra, Caroline Islands, Samoa, Funafuti, etc. Also some Antilles species show remarkable analogy with Mediterranean and E. Atlantic species, both in external characters and in the reproductive organs; yet in anatomical structure they prove to be far asunder. Similar zoological analogies exist, and have given rise to the hypothetical continent of Atlantis. E. S. G.

Corallinaceæ found in a Limestone in course of Formation in the Indian Ocean.—Madame Paul Lemoine (*Bull. Mus. d'Hist. Nat.*, 1917, No. 2, 130–2). The calcareous algæ in question were found in a specimen in a mineralogical collection from the island of Mayotte in the Comoro Archipelago. A deposit of limestone is in actual course of formation at the northern end of the islet Pamanzi, by the accumulation of débris, particularly shells, united in a cement of volcanic débris and small fragments of calcareous algæ. Among these the author has

recognized five different species, one *Lithothamnium*, three *Lithophyllum* and one *Amphiroa*. Three of these were determined specifically, and the remaining two are probably new, but too fragmentary to allow of sufficient description to establish new species. Notes are given on each of the five species, with such distinguishing characters as can be discerned. This investigation proves that calcareous algæ continue to this day, in the constitution of marine deposits, the more or less preponderant rôle that they have played in all geological epochs since Silurian times. This is the first record of calcareous algæ from the Comoro Archipelago, though the neighbouring regions, Seychelles, Amirante, Saya de Malha and Mauritius, are comparatively well known from that point of view. E. S. G.

Note on an Algal Limestone from Angola.—Mrs. M. F. Romanes (*Trans. Roy. Soc. Edinb.*, 1916, **51**, 581–4, 1 pl.). A description of rock-specimens from the Albian beds near Lobito Bay in the province of Benguella, Angola, collected by J. W. Gregory. Two new calcareous algæ are figured—*Girvanella minima* and *Lithothamnion angolense*. A. G.

New Species of Fucus, F. dichotomus Sauv.—C. Sauvageau (*C. R. Acad. Sci. Paris*, 1915, **160**, 557–9). A description of this new species of *Fucus*, which has been found on the "brandes" bordering certain oyster beds, now covered with sand and abandoned, in the harbour of Arcachon. *F. dichotomus* grows only for a few months, and is distinguished from *F. platycarpus* by its flabellate ramification involving the simultaneity and abundance of the receptacles, and by the cylindrical form of the receptacles. The plant being fixed, the adventitious shoots do not propagate the species, but preserve it; and to them is due the extension of life in certain individuals to one or even perhaps two years. E. S. G.

Availability of the Nitrogen in Pacific Coast Kelps.—G. R. Stewart (*Journ. Agric. Research*, *Washington*, **4**, 1915, 21–38). The value of dried and ground kelp as a fertilizer varies with the species. The nitrogen of *Nereocystis Luetkeana* is relatively very available, while that of *Pelagophycus porra* is not. That of *Macrocystis pyrifera* is slowly yielded in the soil, and more quickly when the kelp is fresh or only partially dried. Removal of the salts from the alga does not hasten its decomposition. For easy grinding the *Macrocystis* must be dried crisp, but should not be scorched. The presence of kelp is unlikely to interfere with the ammonification or nitrification going on in the soil. A. G.

Fungi.

Repeated Zoospore Emergence in Dictyuchus.—William H. Weston (*Bot. Gaz.*, 1919, **68**, 287–96, 1 pl., 1 fig.). The fungus described appeared in a culture of moist sand, leaves and other débris taken from a shaded brook near Great Bacrington, Massachusetts. It

was determined as *Dictyuchus* from the retention of spores in the sporangium while they germinated, with the liberation of zoospores. These zoospores were observed to come to rest and encyst. After a time some of these encysted spores germinate by hyphæ. Many of them, however, emit zoospores which are biciliate, and thus exactly similar to those formed in the sporangium. The writer is of opinion that this secondary zoospore formation will be found general in *Dictyuchus*. No sexual organs were formed, and it was thus found impossible to determine the species. A. LORRAIN SMITH.

Study of Synchytrium.—W. RYTZ (*Beih. Bot. Centralbl.*, 1917, **34**, 343–72, 3 pls.; see also *Ann. Mycol.*, 1917, **15**, 289). *Synchytrium Taraxaci* is parasitic in the epidermis of *Taraxacum officinale*. The zoospores penetrate directly from the outside into the host-cell, the latter enlarges, and in due time division of the parasitic nuclei begins up to a large number. Division is always mitotic. A. L. S.

Specialization of Peronospora on some Scrophulariaceæ.—ERNST GÄUMANN (*Ann. Mycol.*, 1918, **16**, 189–99, 4 figs. and diagrams). There is considerable biological specialization among *Peronosporeæ*, and there is also considerable difference in spore sizes. Gäumann has taken up the question with regard to a limited number of what he terms collective species. He describes seven new species. A. L. S.

Study of Plasmopara.—ALFRED WARTENWEILER (*Ann. Mycol.*, 1917, **15**, 495–7; 1918, **16**, 269–99, 3 pls., 12 figs.). The author finds that when a species of *Plasmopara* grows on different hosts, there is considerable variation in conidia and conidiophores. Thus for *Plasmopara nivea* he tested sizes from twenty different hosts. He gives the number of measurements and the average size of spores on each; they vary from $16 \cdot 99\,\mu \times 16 \cdot 21\,\mu$ in the first host in even higher measure to $28\,\mu \times 21 \cdot 48\,\mu$ on the last. He made similar tests for *P. pygmæa* and *P. densa*, which showed somewhat equal variations. The conidiophores were also examined and found to vary according to the host.

In the second paper he continues the study of conidia and conidiophores. He also gives the results of a research on the wintering of *Plasmopara nivea*. He claims to have proved that the mycelium passes the winter in *Laserpitium latifolium*. He has established this in plants from many districts, but cannot say if it is of universal occurrence. He gives in a summary at the end a comparative account of the various species examined. A. L. S.

Classification of the Phacidiales. — FR. VON HÖHNEL (*Ber. Deutsch. Bot. Gesell.*, 1917, **35**, 416–22). The Phacidiales comprise discomycetes without or with a stroma and with a carbonaceous ascoma which opens in lobes. Van Höhnel divides the order into six families. Diagnoses of these and of the genera are given. A. L. S.

Study of Hypocreaceæ.—I. WEESE (*Sitz.-Ber. Akad. Wiss. Wien Math. Nat. Kl. Abhl.*, 1916, **125**, 467–575, 3 pls. 15 figs.). A critical

study of various genera of this family. The author traces affinity between the genera in the form of the perithecium and only secondarily in the septation of the spores. Illustrations are given of twenty-two species. A. L. S.

Mycological Contributions.—T. Theiszen (*Ann. Mycol.*, 1918, **16**, 175–88, 4 figs.). Notes are given on genera of Pyrenomycetes such as *Lasiobotrys* and *Vestergrenia*. The author has also examined material from S. America and from Asia, and publishes a number of new species, with extended descriptive accounts of some that are not new. A. L. S.

Laboulbeniales.—Roland Thaxter (*Proc. Amer. Acad. Arts and Sci.*, 1915, **51**, 1–51; 1915, **52**, 1–54 and 649–721; 1918, **53**, 697, 749; 1918, **54**, 207–32). In this series of papers Thaxter describes many new species from widely separated localities situated in or near the tropics. In the first list, comprising Indo-Malayan species, one of the gatherings provided evidence that the genus *Ceraiomyces* should be merged in *Laboulbenia*. Java and Ceylon furnished most of the material. In the second paper species of *Chitonomyces* and *Rickia* are described. They were collected in the Cameroons, Philippines, W. Indies and Central America. A paper is devoted to American species—not the United States—and includes as new genera *Nycteromyces* and *Ilytheomyces*. A record of extra-American species includes mostly African or Malayan species, while the final paper takes account only of species from Chili and New Zealand. The two countries are associated because the flora of Southern Chili and New Zealand are similar in many respects. A. L. S.

Synoptic Tables.—F. Theiszen and H. Sydow (*Ann. Mycol.*, 1917, **15**, 389–491, 38 figs.). The authors point out that in the twenty years since the publication of the "Natur. Pflanzenfamilien" there have been many changes in the systematic arrangement of various groups of fungi. They deal here with Pyrenomycetes, and have given synoptic tables of the orders Hemisphæriales, Myriangiales and Perisporiales. Tables are given of the families into which these are divided, then the genera of each family and a diagnosis of each genus with the type species and synonymy. A number of new genera have been formed or new names substituted in the course of the work. An index of the genera is given. A. L. S.

Sketch of Pseudosphæriales.—F. Theiszen and H. Sydow (*Ann. Mycol.*, 1918, **16**, 1–34, 5 figs.). In the Pseudosphæriaceæ the loculi of a stroma enclose only one ascus. There are several genera in the family. A full account is given by the authors of this and other families. They also give a special synoptic list of Pyrenomycetes parasitic on the lichen thallus. A. L. S.

Dothideales: a Critical Systematic Original Research.—F. Theiszen and H. Sydow (*Ann. Mycol.*, 1915, **13**, 149–746, 6 pls.). The authors give an historical sketch of the treatment of this group of Pyrenomycetes. Von Höhnel had published an account of these fungi, but his work

remains unfinished. Theiszen and Sydow here give special attention to the stroma in their research, and the arrangement chosen follows on the lines of its growth and mature form. They divide the Dothideales into four families: (1) Polystomellaceæ, with three sub-families—Parmulineæ, Polystomelleæ and Munkielleæ; (2) Dothideaceæ, also with three sub-families — Coccoideæ, Leveillelleæ and Dothideæ; (3) Phyllachoraceæ, divided into Trabutineæ, Scirrhineæ and Phyllachorineæ; (4) Montagnellaceæ, with two sub-families—Eu-Montagnelleæ and Rosenscheldieæ. The last family has a very reduced vegetative stroma, or a basal stroma only, or none. In these families they recognize 140 genera set out in a systematic key. Of these some 64 are new names. A number of well-known genera have been included in others, as, for instance, *Plowrightia*, which gives way to a previous name, *Dothidella*. Each species is fully described, and there is a complete index. A. L. S.

Occurrence of Bulgaria platydiscus in Canada.—A. W. McCallum (*Mycologia*, 1919, **11**, 293–5, 1 pl.). This fungus, originally described from Königsberg in Germany, has recently been found in the valley of the Lièvre River. The plant was allowed to mature, and drawings were made of the peculiar spiral form of the exterior hyphæ. A full description is given. A. L. S.

Contributions to the Systematy of the Ascomycetes.—F. Theiszen (*Ann. Mycol.*, 1916, **14**, 401–39, 1 pl.). Theiszen divides the present "contribution" into three divisions. The first deals with Perisporiaceæ, and notes are given on a number of genera. Two new genera are added to the family—*Stomatogene*, on which the perithecia grow superficially on a brown felted mycelium, but penetrate the leaf through the stomata by a central "foot," is founded on *Asterina Agaves* E. & E. Another genus, *Piline*, is substituted for *Asterina splendens*. The second division discusses various species of *Physalospora*, a number of which are removed to other genera. *Plectosphæra* g. n. replaces *Physalospora Bersamæ* Syd. Several other species are included in the new genus. *Physalospora rosicola* becomes the type of *Schizostege* g. n., and *Physalospora borealis* the type of *Heteropera* g. n. Under Stigmataceæ (the third division) he gives notes on the genera *Stigmatea*, *Coleroa* and *Vigella*. Finally, he discusses various fungi, establishing as new genera *Halbaniella* (Microthyriaceæ) and *Plactogene* (Sphæriaceæ). Theiszen has in this paper established seven new genera. The plants dealt with are herbarium specimens. A. L. S.

Study of Botryosphæria.—F. Theiszen (*Ann. Mycol.*, 1916, **14**, 297–340, 1 fig.). Theiszen gives an historical account of this genus, and then describes its characteristics and affinities. In most of the species the perithecia are embedded in a stroma; only rarely are they isolated. The inner structure of the stroma is not distinctive, and spores are frequently undeveloped in herbarium material. It is necessary, therefore, in distinguishing species to rely more or less on the outward appearance of the fungus. He divides the genus into (1) *Scleropleoidea*, in which the perithecia occur singly, and *Botryosa*, where they are united in a stroma. The *Botryosa* species are further

divided up according to the form of the stroma—round, ellipsoid, elongate, etc. The species described (66) are from herbaria, and thus they have been collected in many parts of the world, though most of them are from America. A. L. S.

Additional Notes on Dothideæ and other Microfungi.—F. Theiszen and H. Sydow (*Ann. Mycol.*, 1916, **14**, 444–53). These notes are on fungi from widely different localities, most of them already described; some are now transferred to other genera. Descriptions and synonymy are given. Two new genera are published—*Phragmosperma*, based on *Micropeltis Marattiæ* P. Henn.; and *Periaster*, based on *Erikssonia spatholobi* Syd. *Periaster* differs from *Erikssonia* in the septate spores. A. L. S.

Mycological Memoirs.—F. Theiszen (*Verk. Zool. Bot. Ges. Wien*, 1915, **66**, 296–400, 1 pl., 14 figs.; see also *Ann. Mycol.*, 1916, **14**, 469–70). The phylogeny of the Pseudosphæriaceæ receives special attention. According to the author the family is closely associated with Myriangiaceæ; the two differ in the more or less complete separation of loculi in the fruiting body. Englerulaceæ are fully described, and as new genera are added *Euthrypton*, *Thrauste*, *Syntexis* and *Ophiotexis*. The genus *Physalospora* is fully described, and to it are added as new genera *Pyreniella*, *Hypostegium*, *Disperma* and *Amerostegi*, the latter placed under Clypeosphæriaceæ. A. L. S.

New Ascomycetes.—H. Rehm (*Ann. Mycol.*, 1915, **13**, 1–6). The fungi described are from Europe and North America. A few have been previously described. Diagnoses and notes are given along with locality and collector. A. L. S.

Some New Fungi.—Fr. Bubák and H. Sydow (*Ann. Mycol.*, 1915, **13**, 7–12, 2 figs.). The species described are microfungi belonging to the Ascomycetes or to the Deuteromycetes, and were collected in various districts of Germany. A new Hyphomycete is described, *Pachybasidiella polyspora* g. et sp. n. It is distinguished by the very broad blunt conidiophores, which bear four to eight conidia at the apex. A. L. S.

New Fungi from Bohemia.—Fr. Bubák (*Ann. Mycol.*, 1915, **13**, 26–34). A considerable number of new species belonging to the Sphæropsideæ are described, and others are critically considered. They are all parasitic on the higher plants; some of them cause serious disease. A. L. S.

Various Contributions.—T. Theiszen (*Ann. Mycol.*, 1916, **14**, 263–73, 6 figs.). Under this heading the author publishes notes on fungi along with descriptions of new forms. He has passed in review a number of species of *Rhytisma* from the Kew Herbarium, now unrecognizable; others are from American collections. A new genus, *Haplophyse* (Hypodermataceæ), from Hawaii has been diagnosed. It grew on leaves of *Coprosma*. Other genera and species are dealt with.
A. L. S.

Genus Parodiella.—F. Theiszen and H. Sydow (*Ann. Mycol.*, 1917, **15**, 125–142). The genus *Parodiella* was based by Spegazzini on *Dothidea perisporiordes*. He described it as a Perisporieæ. The above writers have amended it and have added many new species. Among the forms examined they have detached a number that are not *Parodiellæ*, and among these they find new genera: *Hypoplegma*, *Pseudoparodia*, *Chrysomyces* and *Rhizotexis*. A. L. S.

Origin and Development of the Pycnidium.—F. E. Kempton (*Bot. Gaz.*, 1919, **68**, 233–61, 6 pls.). The author takes up De Bary's view of a twofold origin of these structures: "symphogenous" when the pycnidial primordium arises from an interwoven network of hyphæ; "meristogenous" when the primordium arises from a hyphal cell or a group of adjacent cells of a single hypha by continued cross and longitudinal division. Species belonging to a number of genera were studied chiefly by cultures from spores or hyphæ. The meristogenous method was found to be the most frequent, and in it there are two modes of development: "simple" when the pycnidium arises from a single cell or a few adjacent cells of a single hypha; and "compound" when the cells of adjacent hyphæ take part in the primordium.

Acervuli arise, as do pycnidia. The pseudo-acervulus of *Pestalozzia* develops first as a pycnidium, then breaks open and appears like an acervulus. The different stages of growth are well illustrated.

A. L. S.

Development and Biology of Pycnidia.—H. Schnegg (*Centralbl. Bakt. Abt.* 2, 1915, **43**, 326–64, 25 figs.; see also *Ann. Mycol.*, 1916, **14**, 294–5). A widely spread fungus in breweries was placed in culture, and its development as a *Phoma* was watched. The pycnidia arose, in all cases, from the conidia in the culture-media. One ostiole was usually formed, but several might arise. In thirty to thirty-two hours after sowing, the conidial development would be complete. Wort was found to be the most favourable medium; in other media the fungus gradually degenerated. In the older cultures resting spores of various kinds were formed. The fungus was named *Phoma conidiogena*. A. L. S.

Lists of Fusaria.—H. W. Wollenweber (*Ann. Mycol.*, 1917, **15**, 1–56). The lists compiled by the author are mainly based on his own collections and cultures. He gives first an account of his herbarium, and then a note on the results arrived at. Of the 442 so-called *Fusaria* 180 are true fungus species, but 69 of these belong to other genera, mostly Hyphomycetes. A number also are conidial forms of Ascomycetes, such as *Gibberella*, *Calonectria*, *Hypomyces* and *Nectria*. The relationship between the forms has been established by cultures. A tabulated list is given of all these fungi now determined; a list of the *Fusaria* to be conserved and of those to be excluded; a list of host plants with their parasites; and, finally, diagnoses of a new genus, *Neonectria*, and several new species of *Fusarium*. A. L. S.

Position of the Sorus in Uredineæ and its Value as a Systematic Character.—F. Grebelsky (*Centralbl. Bakt.*, 1915, *Abt.* 2, **43**, 645–62, 12 figs.; see also *Ann. Mycol.*, 1916, **14**, 130). The author

finds that the position of the uredospores depends on the stomata, and they are mostly to be found only on the side of the leaf where they are formed. In certain cases, however, where stomata occur on both surfaces, the uredospores are confined to one. Teleutospores appear very often on the side of the leaf free from stomata. A. L. S.

Some New Roumanian Uredineæ.—J. C. CONSTANTINEANU (*Ann. Mycol.*, 1916, **14**, 268–536, 6 figs.). The author here describes five new species belonging to *Uromyces* and *Puccinia*. Very full descriptions are given, with figures of the various spores. Comparisons are made between the species described and allied forms. A. L. S.

Grass Rusts of Unusual Structure.—J. C. ARTHUR and E. B. MAINS (*Bull. Torrey Bot. Club*, 1919, **46**, 411–5, 2 figs.). The authors remark on the close resemblance of the leaves of *Olyra* (Paniceæ) with those of various bamboos. This has led to some confusion in determining the hosts of their respective rusts, but also there is a curious resemblance between these rusts. Comparisons are drawn between three of them :—*Puccinia pallescens* on *Tripsacum*, *P. phaksopsoroides* sp. n. on *Olyra*, and *Uredo ignava* on the genus *Bambusa*. Tropical rusts frequently produce thin-walled, pale or colourless spores, with a fringe of incurved hyphoid paraphyses. The authors find these characters present in the species examined. A. L. S.

Systematic Position of Uredo alpestris Schröt.—P. DIETEL (*Ann. Mycol.*, 1916, **14**, 98–9). This *Uredo* on *Viola biflora* is frequently found in the Alps. There occur in the sori spores of two kinds : broadly fusiform with a projection at the apex, or ellipsoid and without any projection. Dietel holds that such uredospores are only known in the genus *Uredinopsis*. In other respects also the *Uredo* is similar to that of the above genus. A. L. S.

Research on the Behaviour of the Nuclei in the Reproduction of Smut Fungi.—EUGEN PARAVICINI (*Ann. Mycol.*, 1917, **15**, 57–96, 6 pls., 5 figs.). The author gives an historical account of work done on the reproductive nuclei of fungi. He then sets out the problems still awaiting solution in the Ustilagineæ, and describes the methods he employed in his research. He wished to verify the nuclear fusions already described in Ustilagineæ and Tilletiæ ; to examine further species as to whether in the copulation of conidia and promycelia there was a passing over of protoplasm along with the nuclei, etc. The solution of these and other problems was sought in the germination of spores in artificial cultures of many species. He confirmed the presence of one nucleus in the spore, which divides or germinates, one of the daughter-nuclei passing to the promycelium. The conidia formed on the promycelium are also uninucleate. When two conidia copulate the nucleus and protoplasm of one cell pass to the other. Mycelial cells copulate similarly. A binucleate conjugate condition thus arises and is to be found in the mycelium of infected host plants. Fusion between the conjugate nuclei takes place on spore-formation, and this the author regards as a sexual act. A. L. S.

Researches on the Infection of Cereal Rusts.—G. Gassner (*Centralbl. Bakt.*, 1915, *Abt.* 2, **44**, 512–617; see also *Ann. Mycol.*, 1916, **14**, 285–6). The author has worked for several years in Uruguay on rust infection, and he finds that it is in certain cases influenced by the stage of development reached by the host. This is especially the case in *Puccinia graminis*; young host plants can resist infection during the greater part of the year, while, at a later stage of growth, the plants are more easily infected and the young leaves of these older plants also suffer. Other results were obtained with *P. triticina* and *P. coronifera*. They could infect cereals at any stage up to the time of teleutospore development. The time of maximum infection was found to differ for the various rusts. A warm temperature was favourable to rusts; the physical condition of the soil had no effect, except through greater or less moisture. A high content of nitrogen in the soil was not found to be particularly favourable to infection. Phosphorous manure had no effect except in the case of *P. graminis*, when the host plant may have matured earlier and so reached the infection stage more quickly.

A. L. S.

Sexuality in the Basidiomycetes.—Mathilde Bensaude (*Memoirs*, 1918, 1–150, 13 pls., 30 figs.; see also *Mycologia*, 1919, **11**, 280–3). This is a careful and long study of nuclear phenomena in the mycelia of Basidiomycetes. The writer argues for the sexual significance of the familiar hyphal anastomoses in these fungi. Cultured studies were made from spores and from mycelia gathered in the field. In a culture from spores of *Coprinus fimetarius* she found that mycelium from a single spore grew vegetatively for eight months; there was no carpophore development. With a mixed culture, fruit bodies were formed. She concludes that binucleated cells are formed, following plasmogamy between cells coming from two different thalli, though she also considers that some Basidiomycetes are homothallic, while others are heterothallic, as in the Mucorini. Clamp formations and their importance are fully described and discussed. A. L. S.

Gasteromycetæ Zeylanicæ.—T. Petch (*Ann. Roy. Bot. Gard., Peradeniya*, 1919, **7**, 57–78). Gasteromycetes are very frequent in the tropics and occur under strange forms. T. Petch has published a list of all those collected in Ceylon by himself or others. He gives an account of the collections and of the various determinations of the fungi. A number of new species are included, and a new genus, *Pharus*, is based on *Lysurus Gardneri* Berk. A. L. S.

Revisions of Ceylon Fungi.—T. Petch (*Ann. Roy. Bot. Gard., Peradeniya*, 1919, **7**, 1–44). This is part vi. of Petch's examination of doubtful species; the numbers treated are 218–72, and comprise some of the larger fungi, though mainly microfungi. There is one new genus, *Phæopeltis*, based on *Micropeltis gomphispora* B. & Br. The notes, historical and descriptive, are very full. A. L. S.

Mycological Contributions.—H. and P. Sydow (*Ann. Mycol.*, 1918, **16**, 240–8). The paper deals chiefly with a critical examination of

known species. Of most importance are the species of Uredineæ, of which several new genera are established: *Desmella*, in which the teleutospores are borne on hyphæ that emerge in fascicles through the stomata; *Calidion*, of which the uredospores only are known—in the sorus there are many curved paraphyses; and *Crossopsora*, in which the uredosori are surrounded by curved paraphyses.

In a further paper (*Ann. Mycol.*, 1919, **17**, 33–47, figs.) the same authors deal with microfungi from many localities. They establish as new genera *Starbæckiella* and *Microscypha* (Pyrenomycetes) with *Xenopeltis* (Sphæropsideæ), the pycnidia of which grow on the fructifications of grasses. There is a lengthy discussion on the nomenclature of *Mycosphærella*. A. L. S.

Fungoid Infection of Eggs.—A. Brtnik (*Centralbl. Bakt.*, 1916, *Abt.* 2, **46**, 427–44; see also *Ann. Mycol.*, 1916, **14**, 474). It was proved that eggs from absolutely clean localities and with good handling in transport were extremely resistant to the entrance of fungi up to three months' duration or more. The fungi dealt with were *Mucor mucedo*, *M. stolonifer*, *Aspergillus niger*, *A. glaucus*, *Penicillium glaucum*, and *P. brevicaule*. A. L. S.

Growth of Fungi in Hens' Eggs.—A. Postolka (*Centralb. Bakt.*, *Abt.* 2, 1916, **46**, 320–30; see also *Ann. Mycol.*, 1916, **16**, 476). A number of spoilt eggs were examined, the fungus being due to fungus penetration. The effect produced on the egg varied exceedingly. Postolka found that *Penicillium glaucum* and *Cladosporium herbarum* were the chief agents of fungoid infection, but other fungi might also penetrate and spoil the eggs. A. L. S.

Field Meeting of Pathologists.—William A. Murrill (*Mycologia*, 1919, **11**, 308–12, 1 pl.). Murrill gives here an account of the discussions and excursions at the meeting of plant pathologists at New Haven, Storrs and elsewhere in August. Spraying problems received special attention. Tobacco fields were visited and several diseases affecting the plants were noted. A. L. S.

Synonyms and Mycological Notes.—J. Bresadola (*Ann. Mycol.*, 1916, **14**, 221–42). During some years the author has dealt with fungi from distant lands, and has had occasion to examine many herbarium plants. He has detected a great many errors in determination, and he now publishes a list of synonyms that he has come across. They refer, almost without exception, to Hymenomycetes from other than European countries. In addition to the bare lists he has added notes and short descriptions to a large number. A. L. S.

Mycotheca germanica, Fasc. xxvii–viii. Nos. 1301–1400.—Sydow (*Ann. Mycol.*, 1916, **14**, 243–7). Sydow gives a list of the century of fungi and adds full diagnoses of his new species in the fascicles. They are all microfungi from dead or living leaves or branches of plants.

A. L. S.

Fungi amazonici of E. Ule.—H. and P. Sydow (*Ann. Mycol.*, 1916, **14**, 65–97). A record of the fungi collected by the late E. Ule on his last journey, mostly from Brazil; a few are recorded from Peru. There are many new species of Uredineæ and Ustilagineæ. In the various families of Ascomycetes the species are nearly all new to science. As new genera :—*Cleistosphæra* (Perisporeaceæ); *Haplostroma*, on leaves of *Miconia*, with perithecia immersed in stromata, of doubtful affinity; *Stegastroma* (Clypeosphæriaceæ), with brown 1-septate spores; *Leptocrea* (Hypocreaceæ), in stromata, with oblong simple spores; *Caudella* (Microthyriaceæ), of which the 1-septate spores have a long slender process at the lower end. The Fungi Imperfecti are less numerous, but they include four new genera :—*Pyrenochætina*, near to *Pyrenochæta*, but the pycnidia without pores; *Botryella*, with minute pycnidia in botryose stromata, on leaves; *Hemidothis*, with *Dothidea*-like stromata and filiform spores, on leaves of *Miconia*; and *Marcosia* (Tuberculariaceæ), the conidia of which formed on sporodochia become 3-septate, on leaves of *Cynometra*. A. L. S.

Contribution to the Study of Northern Fungi.—J. Lind (*Ann. Mycol.*, 1915, **13**, 13–25, 4 figs.). This includes a critical study of a number of species. *Puccinia porri* is shown to be the same plant as *Uromyces ambiguus*, but of different form. The differences are fully set forth. The author made culture experiments with *Phoma Rostrupii*, a fungus which causes great damage to *Daucus Carota*; finally, he was able to connect it up with *Leptosphæria Rostrupii* sp. n. A special note is written on *Botrytis cinerea*. Lind repeats his former statement that *Botrytis* is wholly unconnected with *Sclerotinia*. Two other fungi he describes as synonymous—*Fusarium avenaceum* and *Pionnotes Biasolettiana*. The *Fusarium* is a wound parasite; its mycelium spreads out and forms a Stereum-like fruit body—the *Pionnotes* stage. Three Ascomycetes from Finland are also described, two of which are new. A copious bibliography is appended. A. L. S.

Illustrations of Fungi. XXXI.—William A. Murrill (*Mycologia*, 1919, **11**, 289–92, 1 col. pl.). The fungi dealt with are edible. Of the three depicted and described, one—*Pholiota squarrosoides*—is American. The author gives the points in which it differs from the European *P. squarrosa*. A. L. S.

Mycological Notes.—P. A. Saccardo (*Ann. Mycol.*, 1915, **13**, 115–38). Saccardo gives an account of eight sets of Fungi from different countries:—I. *Fungi Noveboracensis* (States of New York and Mass.), collected by H. D. House, number 53 species of microfungi belonging to various families and genera, several of them new species. II. *Fungi Dakotenses*, collected by J. F. Brenckle, 19 species. III. *Fungi Canadenses*, 17 species, collected by J. Dearness. IV. *Fungi Philippinenses*, sent to Hariot by Baker and others, 8 species, nearly all new. V. *Fungi Uruguayenses*, 19 species, transmitted by O. Matterolo, and comprising a number of the larger fungi, Agaricaceæ and Polyporaceæ. VI. *Fungi Moravici et Bohemici*, 22 species, sent by Petrak. VII. *Fungi*

Gallici, Hispanici et Italici, 40 species, sent from these different countries; one new genus, *Heteroceras* (Melanconiaceæ), and a number of new species are described. VIII. *Fungi Australienses*, 2 species of microfungi, one of them new. A. L. S.

Fungi in "Scientific Results of the Expedition to Mesopotamia."—Fr. Bubak (1914, **28**, 189–218, 2 pls.; see also *Ann. Mycol.*, 1915, **13**, 57–8). Many new species are included in this account; they are all of them minute and mostly parasitic species. There are several new genera—*Sclerosphæropsis*, similar to a sclerotial *Sphæropsis*; *Basiascella* (Leptostromaceæ), with one-celled brown spores; *Ramulariospora* (Excipulaceæ), with spores in chains. A. L. S.

New Fungi from Saxony.—G. Bresadola (*Ann. Mycol.*, 1915, **13**, 194–6). The list is accompanied by a note from Krieger, explaining that these are fungi sent by him to Bresadola. They are all microfungi, most of them parasites on branches, leaves, etc. A. L. S.

Seventh Contribution to the Fungus Flora of the Tyrol.—Fr. Bubak and J. E. Kabat (*Ann. Mycol.*, 1915, **13**, 107–14). The authors list 80 different species, most of them already determined; a small proportion are new to science. They are microfungi, and most of them parasites on living plants. A. L. S.

Contributions to the Knowledge of the Fungi of Dalmatia.—Otto Jaap (*Ann. Mycol.*, 1916, **14**, 1–44). A very large number of fungi (510) are here listed by the author. They belong to all the different groups. First on the list are nine species of Myxomycetes and two species of Schizomycetes, bacilli which gave rise to disease of olive trees. Habitat and locality are given in each case. Fifty new species of microfungi have been discovered and described by the author. A. L. S.

Fungus Flora of the Tyrol.—Fr. Bubak (*Ann. Mycol.*, 1916, **14**, 145–58, figs.). This contribution—the eighth for the Tyrol—comprises seventy different species, all of them microfungi and many of them parasites. A large number of new species are described, and the following new genera:—*Cytostaganospora*, in which the pycnidia are covered by a clypeus; *Diplodothiorella*, which differs from *Dothiorella* in the two-celled spores. Bubak also slightly emends the genus *Pedilospora* von Höhn., and adds a second species to it. A. L. S.

Diagnoses of New Philippine Fungi.—H. and P. Sydow (*Ann. Mycol.*, 1916, **14**, 353–75, 1 fig.). The fungi determined were sent by C. E. Baker in 1915. Sydow diagnoses a new genus of Puccineaceæ, *Anthomycetella*, in which the teleutospores are in two series: the upper series of one cell, the lower of six to eight cells, much narrower than the upper. *Setella*, a new genus of Periosporiaceæ, is distinguished by the apical setulæ of the perithecium and the septate spores; *Rhabdostroma*, near to *Scirrhiella*, with subepidermal stromata and colourless spores, one septate near the base; *Stegasphæria*, the representative of a new

family, Stegasphæriaceæ, very near to Clypeosphæriaceæ; and in the same family, *Stegaphora ulmea*, formerly *Gnomonia* sp. Other new genera of Ascomycetes are—*Pycnopeltis* (Trichopeltacearum); *Steganopycnis* (Sphærioideæ); *Discothecium* (Leptostromatæ); and a new genus of Hyphomycetes, *Xiphomyces* (Tuberculariaceæ), with very large continuous acrogenous yellow-brown conidia. A. L. S.

Fungi Papuani.—H. and P. Sydow (*Engler's bot. Jahrb.*, 1916, **54**, 246–61, 3 figs.; see also *Ann. Mycol.*, 1916, **14**, 468–9). These include Basidiomycetes, Ascomycetes and Fungi Imperfecti. A number of new species are described in each group, and as new genera *Scrosperma* (Sphæropsideæ), and *Sarophorum* (Hyphomycetes). A. L. S.

Contributions to Mycology. IX.—Fr. von Höhnel (*Zeitschr. f. Gährungsphysiologie*, 1915, **5**, 191–215; see also *Ann. Mycol.*, 1916, **14**, 122–3). Von Höhnel publishes an account of *Myxosporium*, a genus of Melanconieæ, the species of which grow on branches of trees. He has subdivided it into fourteen new genera, and finds *Myxosporium* as understood by Link and others does not exist. A. L. S.

Fungi from Various Localities.—Fr. Bubak (*Ann. Mycol.*, 1916, **14**, 341–52, 2 figs.). The author deals mostly with new species—one *Entomophthora*, the others belonging to Sphæropsideæ or Hyphomycetes, and mostly collected in Bohemia. A new genus, *Titæospora* (Mucedineæ), is described, with peculiar curved septate spores. It has been found in Europe and America. Another, *Columnophora* (Demetieæ), has been figured and described; it grows on the stroma of *Rhytisma Salicis*. A. L. S.

Mycological Notes.—R. G. Fragoso (*Mem. Real. Soc. Esp. Hist. Nat.*, 1919, **11**, 77–123, 1 fig.). A large number of microfungi belonging to many different families and genera are listed. Several are new to science. Many of them, such as species of *Phyllachora* and *Erisyphe*, are parasitic on living plants. A full index is provided. A. L. S.

Contribution to the Knowledge of the Fungus-Flora of the Philippine Islands.—H. and P. Sydow (*Ann. Mycol.*, 1917, **15**, 165–268, 3 figs.). This list includes representatives of many different groups. Most abundant of all are the Pyrenomycetes, and many of the species recorded are new. The authors have also described new genera; these are:—*Ceratochæte*, *Teratonema*, *Irene*, *Melanomyces*, *Linotexis*, *Bolosphæra*, *Dimerinopsis*, *Bakeromyces*, *Prostigme*, *Linobolus*, *Linocarpon*, *Hyalocrea*, *Epinectria*, *Stereocrea*, *Lasiostemma*, *Chætaspis*, *Pleiostomella*, *Synpeltis*, *Melanoplaca*, *Chætoplaca*, *Eremothecella*, *Yatesula*, and *Peltella*. Among Discomycetes they have also established new genera:—*Benguetia*, with a spreading disc and a dense black hypothecium; *Calloriopsis*, as the name implies, near to *Calloria*; and *Ramosiella*, near to *Ægyron*. In Sphæropsideæ they have placed as new—*Stenocarpella*, *Botryogene*, *Discotheciella*, and *Peltaster*. *Leucodochium* is a new genus of Tuberculariaceæ; the conidia are green coloured. *Fuligo septica* is the only Myxomycete recorded. A. L. S.

New Species of Fungi. XIII.—H. and P. Sydow (*Ann. Mycol.*, 1915, **13**, 34–43, 2 figs.). The fungi described came from many parts, mostly from Asia and Africa. They comprise species of Uredineæ and Ustilagineæ, Ascomycetes and Deuteromycetes. Of special interest are a new species of *Eurytheca* from Trinidad, and a new genus of Demateaceæ, *Cheiropodium.* There are no specialized conidiophores in the latter; the conidia rise directly from the creeping mycelium, which also bears hair-like tufts. *C. flagellatum* grew on living leaves of *Carex* in Japan. A. L. S.

Contributions to the Fungus-Flora of Moravia and Austrian Silesia.—F. Petrak (*Ann. Mycol.*, 1915, **13**, 44–51). The author gives a short list of known fungi, and then describes at length a considerable number of new species of minute Ascomycetes, with copious biological notes.

In a subsequent contribution (*Ann. Mycol.*, 1916, **14**, 159–76) Bubak continues his account of these minute fungi belonging to the Pyrenomycetes and also to Fungi Imperfecti. He again diagnoses many new species. He discusses various specific points, such as the occurrence of the black stroma line in *Phomopsis*, a feature by no means constant.

In a further paper (*Ann. Mycol.*, 1916, **14**, 440–3) Petrak records a new genus, *Cucurbitariella*, with congregate perithecia and brown simple spores. *C. moravica* sp. n. grew on branches of *Prunus spinosa*; four new species of *Phomopsis* are also added to science and to the fungus-flora of Moravia. A. L. S.

Further Contributions to the Fungus-Flora of Switzerland.—Otto Jaap (*Ann. Mycol.*, 1917, **15**, 97–124). This is a second list of Swiss fungi by the author. The species were collected by him in a journey through Switzerland in the summer of 1910, and at Lugano in 1913. He gives a short list of Myxomycetes. The fungi are all micro-fungi, belonging to many different groups. A number of species are new to science. A. L. S.

Fungi Indiæ Orientalis. Part V.—H. and P. Sydow and E. J. Butler (*Ann. Mycol.*, 1916, **14**, 177–220). The present contribution deals with Sphæropsideæ and a few Melanconieæ. H. Diedecke helped in the determination of the new fungi. Many of the new species are parasites on Indian plants, and were collected in various parts of India. The new genera are: *Phyllostictina* Syd., which differs from *Phyllosticta* in that the spores are involved in mucus; *Pleosphæropsis*, in which the spores become brown; *Cystophæra* Died., nearly akin to the preceding, but differing in the absence of mucus; *Plenozythia* Syd. (Nectrioideæ), with simple spores; and *Diplozythiella* Died., with two-celled spores. There is also a new genus in Leptostromataceæ, *Sirothyrium* Syd., in which the membranaceous stroma is not stellate as in *Sirothyriella.* A. L. S.

Novæ Fungorum Species. XIV.—H. and P. Sydow (*Ann. Mycol.*, 1916, **14**, 256–62, 1 fig.). Sydow gives diagnoses of fungi mostly from

tropical lands, from India, Philippines, etc. A number of them are Uredineæ. There is one new genus, *Stilbodendron camerunense* (Stilbaceæ), from the Cameroons. The fruiting bodies are erect and rather long and brightly yellow, and covered the whole length with fertile hyphæ that bear chains of conidia. A. L. S.

Lichens.

New or Better-known Lichens.—A. Hue (*Ann. Mycol.*, 1915, **13**, 73–103). Abbé Hue describes a considerable number of new species, many of them from China and Japan. Most of them belong to the genus *Lecanora*, as understood by him. Very lengthy and detailed descriptions are given of each species, but chemical reactions are mostly ignored. Several species described formerly by himself and others are emended. A. Lorrain Smith.

New Lichens. VIII.—A. Zahlbruckner (*Ann. Mycol.*, 1916, **14**, 45–61). The present contribution includes twenty-five lichens from Japan, most of them new to science. They are very fully described, and their affinities with other species are indicated. In footnotes the author has given keys to Japanese species of *Pyrenula* and *Hæmatomma*.
A. L. S.

German and Austrian Lichens as Food and Fodder.—C. Jacobi (*Tübingen, Mohr*, 1915, 8vo., 16 pp.; see also *Ann. Mycol.*, 1916, **14**, 142). Owing to war conditions the economic value of lichens had to be tested. The author found that Iceland moss (*Cetraria islandica*) was rich in starch-content and valuable as food, if the bitter principle were removed. Instructions are given how to deal with the plant. He proved also that *Cladonia rangiferina*, the reindeer moss, was a valuable fodder for pigs.
A. L. S.

Lichenes in A Ginzberger: Contributions to the Natural History of Scoglien and the Smaller Islands of South Dalmatia.—A. Zahlbruckner (*Denkschr. K. Akad. Wiss. Wien Math.-Naturw. Kl.*, 1915, **92**, 301–22; see also *Ann. Mycol.*, 1916, **14**, 142–3). The lichens enumerated (126 species) belong to the "Adriatic Lichen-region," and they are similar to those already collected on the larger islands. Additions have been made of lichens on primitive rocks. Very characteristic species from North Africa were found. As a whole these Adriatic lichens resembled East rather than West Mediterranean forms. A. L. S.

Morphological and Biological Observations.—K. Goebel (*Flora*, 1915, **108**, 311–5). In the mountains of Brazil a species of Ephebaceæ was frequently found on stones in waterfalls. The specimens were all sterile, and could not be determined; the algal cells belonged to *Stigonema*. The noteworthy fact is the unusual formation of haustoria in the hyphæ, and their penetration into the algal cells, which were ultimately killed. The fungus in this instance was a true parasite.
A. L. S.

Characteristic Constituents of Lichens.—O. HESSE (*Journ. Prakt. Chemie*, 1915, **93**, 254–70; see also *Ann. Mycol.*, 1916, **14**, 480). In this contribution Hesse deals mainly with the starch-content of certain lichens. As compared with the potato, the starch of *Cetraria islandica* is 1 : 2·35, in reindeer moss 1 : 2·5. These two lichens are therefore valuable as human food or as fodder for cattle. In the former case the bitter principle contained in the plant must be eliminated. A. L. S.

Lichenographical Notes.—D. STEINER (*Oesterr. Bot. Zeitschr.*, 1915, **65**, 278–92; see also *Ann. Mycol.*, 1916, **14**, 397–8). In the first three chapters of this work Steiner deals with the section *Aspicilia* of the genus *Lecanora*; certain species have been critically studied and described. He has shown also that the genera *Placolecania* and *Solenospora* are synonymous, and that the latter has priority. The genus *Acaraspora* has also been examined with reference to the compound apothecia characteristic of some species; some of these associated hymenia have a common exciple, others retain separate margins, and are known as "Apothecia composita." He contrasts the formation of pycnidia, which may be associated and show chambered interiors.
A. L. S.

The Lichen-Flora of Hertfordshire.—ROBERT PAULSON (*Trans. Hertf. Nat. Hist. Soc.*, 1919, **17**, 83–96, 1 pl.). Two previous lists of lichens had been made for Hertfordshire, the second of the two, in 1902, numbered sixty-seven species. Paulson now records 143 species, varieties, or forms. Attention is directed to the habitat of the lichens with reference to light intensity and to the soil, which even affects the number of tree-lichens. The number of saxicolous lichens recorded has been greatly increased. The author has himself verified the lichens recorded with the exception of nine species. A. L. S.

Lichen-Flora of Kazan.—CONST. MERESCHKOVSKY (*Hedwigia*, 1919, **61**, 183–241, 1 pl.). The author describes the country round Kazan—flat and without any rocky formations. The flora is therefore soil or forest, and the absence of rocks is reflected in the prevailing type of lichen vegetation. There is also a complete absence in his list, as he himself notes, of *Stereocaulon*, *Nephroma*, *Opegrapha*, and Collemaceæ. There is, further, an almost complete lack of *Ramalina*, which he explains (?) by the distance from the sea. A predominant genus is *Physcia*. In certain forests the trees are covered with grey or white spots, the thallus of various *Physciæ*. Mereschkovsky has described many new varieties and forms of well-known and variable lichens. A. L. S.

Discussion of Parmelia camtschadalis.—CONST. MERESCHKOVSKY (*Hedwigia*, 1919, **61**, 303–7). Certain authors having affirmed the absence of this lichen in Kamschatka, Mereschkovsky brings forward facts to prove that the lichen in question is found there, that is has been found at Geneva, and that it is autonomous, and not identical with *Evernia furfuracea*. A. L.

Relation of Silicicolous Lichens to the Substratum.—E. Bachmann (*Ber. Deutsch. Bot. Ges.*, 1917, **35**, 467–76, 8 figs.). The author found that the hyphæ of *Lecidea crustulata* left no trace on quartz crystals. He noted that the rhizoids of *Parmelia subaurifera* swelled at the base into a somewhat stellate "foot-plate," which consisted of mucilage cells. A hollow space between the foot-plate and the lower surface of the thallus served as a "damp chamber," and therefore the rhizoids of this species serve as water conductors and water storers. A. L. S.

Relation between Algæ and Hyphæ in the Lichen-thallus.—W. Nienburg (*Zeitschr. Bot.*, 1917, **9**, 529–43, 1 pl., 6 figs.). The author, while criticizing recent work by Elfving, records the results of his own researches: that algæ are transported within the thallus by "push-hyphæ" from the gonidial zone to positions in the cortex; and also that cases of parasitism occur in *Evernia furfuracea*. On this account he regards the relationship between the components of the thallus as helotism. A. L. S.

Botanical Results of the Swedish Expedition to Patagonia and Terra del Fuego, 1907–9. VI. Lichens.—A. Zahlbruckner (*Kgl. Sv. Vet.-Akad. Handl.*, 1917, **15**, No. 6, 1–62). The author indicates the sources from which he received the material examined—a few saxicolous specimens from the Swedish Expedition, 1901–3; P. Dusén's collection under Nordenskjöld; also those collected by Skottsberg in the 1907–9 Expedition. He describes a large number of species, new and old; and he gives a tabulated list of all the lichens from the Falkland Islands. A. L. S.

Lichens from the Neighbourhood of Hamburg.—J. Erichsen (*Verk. Naturw. Ver. Hamburg*, 1917, **24**, 65–100; see also *Ann. Mycol.*, 1917, **15**, 509). A description of the more unusual lichens. A large number are new to the district. The author has given a full account of the species, with full biological details. A. L. S.

Lichens of Dune Rubble at Pelzerhaken.—J. Erichsen (*Allgem. Bot. Zeitschr.*, 1916, **21**, 79–85 and 138–16; see also *Ann. Mycol.*, 1917, **15**, 508–9). The dunes examined are in Holstein. Most of the lichens collected were dark-coloured forms, and were characterized by minute apothecia and spores. Degenerate thalli were fairly frequent. A. L. S.

Research on Lichens in Polarized Light. — L. Säntha (*Bot. Kozlemények*, 1916, **15**, 99–101 and 31–2; see also *Ann. Mycol.*, 1917, **15**, 510–11). The author has examined sections of the thallus of various *Physciæ* under polarized light. He finds curious differences in the amount of light transmitted. Mostly the upper cortex is clear; the other layers are clear or dark according to the group. He distinguishes five types, of which the last, the *Obscura* group, remains wholly dark. A. L. S.

PROCEEDINGS OF THE SOCIETY

AN ORDINARY MEETING

OF THE SOCIETY WAS HELD AT THE NORTHAMPTON POLYTECHNIC INSTITUTE, E.C., ON WEDNESDAY, DECEMBER 17TH, 1919, MR. R. PAULSON, VICE-PRESIDENT, IN THE CHAIR.

The Minutes of the preceding Meeting were read, confirmed, and signed by the Chairman.

The nomination papers were read of five Candidates for Fellowship.

New Fellows.—The following were elected Ordinary Fellows of the Society :—

Mr. Bihari Lal Bhatia, M.Sc., F.Z.S.
Mr. Ernest Roadley Dovey, A.R.C.S., A.I.C.
Mr. Gano Dunn, A.I.E.E.
Mr. John Beach Fleuret.
Mr. Norman Lissimore.
Mr. Cecil Willoughby Poignand, M.A., R.N.
Mr. Ernest Willie Pougher, M.M.A.E.
Mr. V. V. Ramanan, M.A., Ph.D., F.R.A.S., F.Z.S., etc.
Mr. Harry Watkinson.
Mr. James Ewart Whipp, M.P.S.

Honorary Fellow.—Mr. Albert D. Michael (President of the Society 1893–96) was elected an Honorary Fellow.

Donations were reported from :—

Messrs. H. F. Angus and Co.—
Spencer Lens Vertical Illuminator.

Messrs. Chapman and Hall, Ltd.—
"Bacteriology and Mycology of Foods" (F. W. Tanner).

On the motion of the **Chairman**, hearty votes of thanks were accorded to the donors.

Auditors.—Mr. Hiscott and Mr. Mortimer were elected Auditors for the ensuing year.

It was announced that the next Meeting of the Biological Section would be held on January 7th, when Dr. J. A. Murray would read a communication on "The Manipulation of Frozen Sections of Animal Tissues."

The Meeting was held during the Society's

CONVERSAZIONE

at the Northampton Polytechnic Institute, St. John Street, E.C.1
(by kind permission of the Governing Body).

A Reception was held by the **President**, Mr. J. E. Barnard, at 7.0 p.m.

General Exhibits were given by :—

M. A. Ainslie, R.N., F.R.M.S.—Diatom structure under high-power objective.
H. F. Angus & Co.
Charles Baker.
J. E. Barnard, P.R.M.S.—Coloured Drawings of various microscopical objects.
R. & J. Beck, Ltd.
M. Blood, M.A., F.R.M.S.—Brittle Starfish illuminated by means of a Lieberkuhn ; also Opal in matrix.
Cambridge & Paul Scientific Instrument Co., Ltd.—Cambridge Reading Microscope and Dissecting Lens Stand.
Prof. F. J. Cheshire, C.B.E., F.R.M.S.
Prof. J. W. H. Eyre, M.D., F.R.M.S.—Preparations of the Influenza Germ.
G. H. Gabb—An Instrument made about 1760 to demonstrate the curious effect of bending the rays of light by means of a prismatic lens.
Prof. R. T. Hewlett, M.D., F.R.M.S
Miss A. Hibbert-Ware, F.L.S.—Braconidæ and Chalcididæ taken from Aphides which they destroy.
C. F. Hill, F.R.M.S.—Specimens of Iron and Steel prepared for microscopical examination.
Miss G. Lister, F.L.S.—Sections of leaves of grasses.
Miss L. Lyle, F.L.S.—A new species of *Chantransia.*
J. Rheinberg, F.R.M.S.
E. J. Sheppard, F.R.M.S.—Longitudinal transverse section through head (eye-region) of the Rat Flea.
C. Singer, M.A., M.D., F.R.M.S.—Exhibition of Pictures from Ancient Herbals from the 11th to 15th Centuries.
T. J. Smith, F.R.M.S.—Shell of *Planorbis nitidus* (polarized).
R. B. Turner & Co.—Stains and Microscopical Re-agents.
T. E. Wallis—Preparations of various objects (spiders, insects, liverworts) mounted in Amyl-Sandarac.
W. Watson & Sons, Ltd.
F. Welch—Staining Bacteria (demonstration).
S. Wycherley, F.R.M.S.—Monocotyledonous stem (Rattan cane).

By the kindness of **Dr. R. Mullineux Walmsley**, Principal of the Northampton Polytechnic Institute, a Practical Exhibition of Lens Grinding and Polishing was given by Students of the Institute.

Pond Life Exhibits were given by the following Fellows of the Society and Members of the Quekett Microscopical Club :—

S. C. Akehurst. F.R.M.S.
W. H. L. Baddeley.
C. H. Bestow, F.R.M.S.
A. J. Bowtell.
N. E. Brown.
J. Burton.
W. R. Chappell.
F. W. Chipps.
T. N. Cox.
E. Cuzner, F.R.M.S.
D. Davies, F.R.M.S.
H. Goullee.
H. F. Green.
J. Grundy, F.R.M.S.
A. Hardcastle.
C. E. Heath, F.R.M.S.
T. H. Hiscott, F.R.M.S.
J. T. Holder.
C. H. Huish, F.R.M.S.
H. E. Hurrell, F.R.M.S.
J. J. Jackson.
H. H. Jewell.
A. Morley Jones.
H. J. Lawrence.
J. Rudd Leeson, F.R.M.S.
E. R. Martin.
H. H. Mortimer, F.R.M.S.
J. C. Myles.
E. R. Newmarch.
J. M. Offord, F.R.M.S.
R. Paulson, F.R.M.S.
E. A. Pinchin, F.R.M.S.
F. J. W. Plaskitt, F.R.M.S.
J. L. Ribbons.
J. Richardson, F.R.M.S.
W. Russell.
D. J. Scourfield, F.R.M.S.
R. S. W. Sears, F.R.M.S.
C. D. Soar, F.R.M.S.
B. J. Thomas.
R. H. Thomas.
C. Tierney, D.Sc., F.R.M.S.
C. Todd.
W. R. Traviss.
C. Turner.
G. Watts, L.D.S., F.R.M.S.
J. Wilson, F.R.M.S.
C. L. Withycombe.
G. W. Young, F.R.M.S.

Photomicrographic Exhibits were given by the following Members of the Photomicrographic Society :—

A. W. Aldis—Photomicrographs.
W. H. Baddeley—Microscope and objects (chiefly diatoms) and accompanying photomicrographic prints.
J. G. Bradbury—Microscope and objects and accompanying photomicrographs in colour and monochrome ; also a frame of photomicrographic transparencies.
C. A. Bunnin—Microscope and objects and photomicrographs.
E. Cuzner, F.R.M.S.—Photomicrographs in colour and monochrome in a viewing frame, and stereoscopic photomicrographs.
F. Martin Duncan, F.R.M.S.—Photomicrographic prints.
E. A. Pinchin, F.R.M.S.—Photomicrographic prints of diatoms.
J. H. Pledge, F.R.M.S.—Photomicrographs and light filters, etc.
A. E. Smith—Microscopes and objects, and accompanying photomicrographs ; also stereoscopic photomicrographs.
H. C. Whitfield and W. R. Biss—Photomicrographic apparatus, with microscopic objects projected in a photomicrographic camera.

During the evening **Selections on the Organ** were given by Mr. **Seymour Dicker.**

THE SYMPOSIUM.

The Royal Microscopical Society, the Faraday Society, the Optical Society, and the Photomicrographic Society in co-operation with the Technical Optics Committee of the British Science Guild, meeting in joint session, held a Symposium and General Discussion on

"THE MICROSCOPE: ITS DESIGN, CONSTRUCTION AND APPLICATIONS,"

on Wednesday, January 14th, 1920, by kind permission of the Royal Society in its Rooms at Burlington House, W.1.

The meeting extended over two sessions: from 4.15 to 6.30, and from 8.15 to 10.30 p.m. During the afternoon preceding the meeting an Exhibition was held illustrating recent developments in the Science of Microscopy and the latest applications of the Microscope in various branches of industry. There was an attendance of not far short of one thousand. The proceedings were of an enthusiastic nature, and the Exhibition was probably the most important ever held on this subject.

Sir Robert Hadfield, Bart., D.Sc., D.Met., F.R.S., President of the Faraday Society, presided over the Discussion, and delivered an Introductory Address.

The Chairman opened with a brief history of the Societies taking part in the Symposium, and explained how the question of such a Symposium first arose. He pointed out the unenviable position of the British Optical Industry at the outbreak of war and the necessity of ensuring that such a condition of affairs should never recur. He then gave a short history of the microscope from ancient times up to the present day, touching on the work of those who have contributed to the development of this powerful instrument of research. Subsequently he dealt with the application of the microscope to modern metallurgy, emphasizing some of the subsidiary points which must be attended to for complete success. In addition, he dealt with certain aspects of crystallography, and with the ultra-microscope, two subjects which are intimately related to the work of the modern microscopist. An addendum to his Address consists of a short Bibliography of some of the most important work relating to microscopy and metallography. The printed Address is accompanied by many plates and figures, including portraits of Sorby and Dallinger.

Mr. J. E. Barnard, President of the Royal Microscopical Society, delivered an address in which he indicated future lines of development in microscope design and in microscopy.

The address considered the microscope chiefly as used in biological research. The modern microscope was mechanically far more unstable

than it was fifty years ago, and they must aim at producing a stable optical bar with all parts adjustable and removable.

The question of resolving power was considered, and its relation to the wave-length of the light. Limits of visibility were much extended with a bright object against a darker ground, and the use of invisible radiation of small wave-length, perhaps even soft X-rays, would extend the limits of resolution.

Mr. F. Martin Duncan, F.R.M.S., F.R.P.S., F.Z.S., President of the Photomicrographic Society, gave a résumé of his paper, "Some Notes on the History and Design of Photomicrographic Apparatus," drawing special attention to the following points :—

The discovery of photography was due to British and French scientists, and the first to apply successfully photography to the recording of microscopic objects were Fox-Talbot in England (1835), Daguerre in France, and Draper in America. Since that date all the important advances and discoveries in photography had been made by scientific workers in those three countries. He drew particular attention to the admirable design of photomicrographic apparatus by British manufacturers in pre-war days, and to the superiority of the best British microscope stand for accurate research work and photomicrography.

Sir Herbert Jackson, K.B.E., F.R.S., emphasized the objects of the Symposium, which were to consider methods of promoting the science of microscopy, developing and improving the instruments, and extending their use in science, industry and education.

Beginning with the subject of glass, he said that while our makers could equal the best obtained from abroad, new glasses were needed with optical constants different from those at present known if new and improved optical combinations were to be achieved.

Mathematical investigations in the design of lenses and optical systems were in progress, and they foreshadowed important developments, but much experimental work would be necessary.

The growing use of the microscope in industry called for systematic education in theory and practice. He drew attention to the new School of Technical Optics at South Kensington, and pleaded for support and encouragement. Lack of knowledge often led to wrong interpretation of results and to the consequent neglect of the instrument. Training, such as was given in spectroscopy, was essential, and he outlined the kind of course he had in mind, an important feature of which was the study of the use of the microscope under all conditions of illumination and powers.

Professor F. J. Cheshire, C.B.E., President of the Optical Society, followed with a paper on "The Mechanical Design of Microscopes."

He showed how the microscope was the keystone of the arch of a key industry, and therefore its manufacture must be in a healthy and thriving condition. To effect this "mass production" must follow the stage of "artistic production," depending on extraordinary personal skill. It must meet the demands of the manufacturer as well as of the user, and therefore be made cheaply as well as accurately. This called

for specialisation, standardisation and repetition production, but design came first. A thorough overhaul of design without reference to traditional designs must lead to startling results.

Dr. Charles Singer, F.R.M.S., contributed a paper in which he outlined "The Earliest Steps in the Invention of the Microscope."

The author dwelt not on the well-known work of the classical observers Leeuwenhoek and his successors, but he reverted to the earliest stages in the discovery of the microscope, beginning with the work of Euclid, and passing through that of Ptolemy and Alhazen to Roger Bacon, who was truly the father of microscopy. Jansen of Middleburg is usually regarded as the first to construct an actual microscope, with Lippershey of Wesel as a rival, but Galileo was the first effective discoverer of the microscope as of the telescope.

Professor Alfred W. Porter, D.Sc., F.R.S., spoke on "The Resolving Power of the Microscope."

The paper consists in part of a brief historical summary. Emphasis is laid on the entrance of the human element into the question of resolving power. It is the "thing seen" with what we have to do; and no two people can see precisely alike. Nor can any *unique* limit be fixed applying indifferently to various shapes of object and various modes of illumination. Under best conditions two lines will not be resolved by a dry objective unless they are more than half of a wavelength apart. Even then they will not be seen as separate unless the magnification reaches such a value that the ultimate image subtends at the eye an angle greater than two minutes' of arc; and if it is desired to detect their separation with ease, an angle considerably greater than this is desirable.

More attention should be paid to the size of the Ramsden circle (the bright spot), which is small in most microscopic cases. The image probably begins to deteriorate in quality, owing to the reduction in the beam entering the eye, when the total magnification with a one-twelfth is about 300. The eye, however, is a fairly long-suffering organ. In the paper it is throughout assumed that the optical system is perfect from the point of view of geometrical optics. This is never the case; and improvements in this respect must be made *pari passu* with increase in numerical aperture.

Professor A. E. Conrady contributed some "Notes on Microscopical Optics," which were communicated by Professor A. W. Porter.

The paper deals with the points in which the actual construction of a lens may be improved. The defects considered are spherical and chromatic aberration, the secondary spectrum (which requires fluorite glasses for its correction), and curvature of the field. It is indicated how it may be possible to combine moderate curvature of field with apochromatic perfection and thus remove the outstanding defect of the best objectives. Defects in condensers are also discussed and remedies suggested.

The author is of opinion that advances in numerical aperture offer little attraction. Abbe carried the N.A. too far, and no notable discovery had been achieved with his monobromide-immersion objectives of N.A. 1·60. The rise in ultra-violet light was more promising, but the technical difficulties and limitations were great.

Dr. R. Mullineux Walmsley, Chairman of the Technical Optics Committee of the British Science Guild, outlined the work of that Committee.

The first step taken was the Conference held in 1915, as a result of which three specifications were drawn up, one for a pathological microscope, another for a student's, and a third for a metallurgical microscope. These specifications were published in 1916, and amended specifications are now about to be issued.

Mr. Conrad Beck, C.B.E., F.R.M.S., read a paper describing "A Standard Microscope," which his firm was making, to fulfil the requirements of the British Science Guild Specification.

The form and dimensions of the microscope are described in detail in the paper. The novel features include the fine adjustment, a new object glass changer possessing many advantages over a revolving nose-piece, and a new micrometer eyepiece and system of measurement.

A supplementary paper emphasized the necessity for research on the use of the microscope. The search for an illuminator by which much larger angles could be used in the object glass, and a method of illumination which would modify the diffraction-images, seen for example when micro-organisms were examined by dark-ground illumination, were cited as instances of such researches. Other examples were the relation between resolution and the increase of brilliancy induced by wide apertures in the condenser, and in metallurgical work a means of illumination to eliminate flaw and ghost images.

Mr. F. Watson Baker, F.R.M.S., spoke on "Progress in Microscopy from a Manufacturer's Point of View."

So long as thirty-eight years ago microscopes were made in this country which anticipated the requirements of to-day, and when apochromatic objectives were first introduced the only microscope which allowed of the full advantage being taken of the optical qualities was the British instrument. British makers had always excelled in the making of microscopes of high class, involving skilled hand work.

The hand-workers of the past had, however, become reduced by dispersion and death, and partly on this account, and in order to reduce the present heavy costs, steps had been taken to produce microscopes by means of machine tools, and such instruments would be available in the near future.

Mr. Powell Swift read a paper on "A New Research Microscope," which described a model shown embodying the results of consultations held between makers and users.

The special points considered are rigidity; diameter of body, which is 2 inches, enabling a photographic lens placed in its interior to cover a large field; and the novel construction of the substage, which is of great advantage for physical research, as it enables special apparatus to be introduced and produce, as occasion may require, a most perfect optical bench for general experimental work. There is a considerable class of delicate optical research which calls for an optical bench possessing the perfect adjustments of a microscope, and hitherto this requirement has not been met. Almost any class of apparatus could be applied to the stand for making small and accurate measurements in physics, and although the chief object of this instrument is to provide the most perfect microscope that can be required, the other function for such an instrument has been borne in mind.

The Chairman having invited discussion on the three papers first presented :—

Mr. J. E. Barnard announced that at the suggestion of some of the makers a small standing committee would be appointed, consisting of the Presidents of the Societies meeting that evening and one or two others, to test the apochromatic objectives now being manufactured by English firms.

Dr. R. Mullineux Walmsley said that to enable microscopes to be successfully produced in large quantities called for thoroughly trained men in the inspection room of the factory. The educational aspect was therefore all-important.

Lieut.-Col. Gifford criticised existing apochromatic objectives on the ground that they were mostly not truly apochromatic.

Instructor-Commander Ainslie spoke on apochromatic objectives from the point of view of resolution. While the best English lenses he had used were of superlative excellence, he urged the necessity for a far higher average of excellence than was the case at present.

Dr. E. C. Bousfield also spoke on apochromatic lenses and the conditions required for making them perfect and lasting. A fault difficult to obviate was roundness of field. He described a better distance focusing arrangement for photomicrographic work than that usually employed.

Dr. W. Rosenhain, F.R.S., pointed out that it was important to distinguish between mass production of a standard microscope and the progress of the microscope as an instrument of research and precision.

Mr. Arthur Banfield, in a written communication, suggested possible improvements in the microscope as a result of his experience.

The following papers were presented and taken as read :—

"Notes on the Future of the Microscope," by M. Eugene Schneider.

(*a*) *Mechanical Improvements.*—A universal screw is suggested for the tubes in which eyepieces and condensers slide.

(*b*) *Optical Improvements.*—We are restricted, at least in usual practice, by the impossibility of going beyond the numerical aperture of 1·40. Better correction of the aberrations and especially of the field

curvature seem only to be possible by the creation of new optical materials. The use of ultra-violet rays admits of increasing the definition to a considerable degree; but the insufficient transparency of media frequently imposes a limit.

"A New Microscope Illuminator," by Mr. ALEXANDER SILVERMAN.

The illuminator described is largely used in America. It is claimed to show greater detail than older forms when examining opaque objects, such as metals, and it is of special value for papers, textiles, etc., which are invisible under vertical light.

"Some Problems in High Power Photomicrography," by Dr. R. E. SLADE, F.I.C., and Mr. G. I. HIGSON, M.Sc.

The paper describes devices to ensure the greatest possible resolving power in examining photographic emulsions. The source of light is a "Pointolite" lamp. No optical system—merely a colour screen for reasons explained—is interposed between the lamp and the condenser. A vibrationless shutter operates in front of the eyepiece of the microscope; no camera is employed.

Mr. R. J. E. HANSON, F.R.C.S., contributed a paper on "Fatigue Factors Incidental in the Use of Certain Optical Instruments," which was taken as read.

Defects in or moisture of the muscular mechanism of eye-movement are considered, as they concern the microscopic observer. A head-piece is described which obviates fatigue, which can be attached to any standard microscope.

A group of papers dealt with the subject of "Glass for Optical Purposes."

Dr. MORRIS W. TRAVERS, F.R.S., referred to the work done in America in 1917, when a sudden demand arose for an enormous supply of optical glass. No information existing in this country was obtainable on that occasion, but by June 1918 a group of twenty scientific men from the Geophysical Laboratory and the Bureau of Standards co-operating with the industry succeeded, after two months' concentrated effort, in producing the quantities required and in qualities that seldom called for rejections. He deprecated the Government policy in this country of attempting to monopolise science.

Dr. W. E. S. TURNER dwelt on the difficulties involved in making optical glass, the demand for which was so small, and he suggested remedies for meeting them. He considered England could supply all her own needs, and he thought America behind this country in output and variety; indeed, there was a market for glass made here.

He forwarded to the meeting a beautiful specimen of a crystal of calcium fluoride from Johannesburg.

Mr. ROBERT MOND read a note relating to the occurrence of fluorite in Canada, and he submitted a specimen from the one deposit that showed any promise. A lens would be cut from it to test its optical properties.

Mr. F. Twyman read a paper on "The Annealing of Glass."

Badly annealed glass meant the presence of internal stress. The annealing range of temperature is the limited intermediate one during which stresses take some little time to die out, and an accurate knowledge of the mechanical properties of glass in this region is necessary.

The remaining papers and communications dealt with various applications of the microscope.

Dr. J. W. Evans, F.R.S., spoke on "The Requirements of the Petrological Microscope."

Besides having the functions of an ordinary microscope, the petrological microscope had to identify crystals by the action of light upon them. The provisions specially designed for this purpose were described.

Mr. A. Chaston Chapman, F.I.C., spoke on "The Application of the Microscope to the Selection and Control of Yeast employed for Brewing Purposes."

It is possible to detect the contamination of the pitching yeast of the brewery with bacteria and undesirable yeast species and to take the necessary steps to purify it.

Lantern slides were shown illustrating this fact.

Dr. R. S. Willows, M.A., presented a paper describing "The Microscopic Outfit of a Textile Research Laboratory."

It is pointed out that the design of a microscopic outfit for research on textiles has not yet received due attention. Attention is particularly directed to the importance of considering more fully the mechanical design of the photographic apparatus, so as to lessen the effects of vibration; the provision of a simple method of changing from transmitted to vertical illumination and of a reflecting device to enable a vertical microscope to be used with a horizontal camera, in cases where the effect of solutions is being followed.

The next group of papers dealt with the use of the microscope in metallography.

A paper by Sir Robert Hadfield, Bart., on "The Great Work of Sorby of Sheffield," introduced the subject.

The late Dr. Sorby, the founder of the science of metallography, first worked as a geologist on transparent rock sections, but he subsequently realized the immense advantage of the application of the microscope to the structure of metals, his first paper on this subject being read in 1864. His earlier work was for some years neglected, but in view of the immense strides which were subsequently made in the science of metallurgy, the microscope, in the hands of such men as Martens, Osmond and le Chatelier, became one of the most powerful instruments of research. To Sorby, however, belongs the credit of having first evolved the microscope method; it was his discovery of the means whereby the structure of a metal can be laid bare that gives him the right to this title.

Dr. W. Rosenhain, F.R.S., read a paper on "The Metallurgical Microscope."

The principal requirements of the metallurgical microscope are sum-

marized. Rigidity is essential. It is shown how the instrument can be designed on the basis of a machine tool, Large working distance between stage and objectives and freedom of movement for the specimen are important.

The optical requirements are those common to all the most exacting microscopic work, but ever-increasing demands are being made on resolving power, since metallurgical progress tends to the production of material of extremely minute microstructure.

The accessories are of some importance, particularly the illuminator. For visual purposes a source of light behind ground glass or opal is recommended, no lenses or condensers being necessary. A suitable arrangement is described.

The author finally describes his optical levelling apppliance for mounting specimens with their surfaces at right angles to the optic axis.

Dr. Rosenhain, in the course of the discussion, pointed out that one method of getting higher resolving power was to use a front glass of higher refractive index than was at present obtainable. It was doubtful whether a satisfactory and lasting glass could be found, but he thought the solution lay in finding or perhaps growing artificially a crystalline substance.

Professor Cecil H. Desch, D.Sc., contributed some "Notes on the Construction and Design of Metallurgical Microscopes."

The author begins with some criticisms of the existing types of instrument, which, while well designed mechanically, do not wear satisfactorily. He proceeds to discuss in some detail the principal parts of the instrument.

The Stand.—A heavy horseshoe foot is recommended on the whole; other forms are useful for special purposes. The Le Chatelier inverted stand is pronounced flimsy and needing better design, because specimens are quickly examined in it.

For larger instruments used for photography the ordinary design might be completely departed from and a type of optical bench devised.

Adjustments.—All racks and screws should be cut in hard, incorrodible metals or alloys, adopting engineering methods.

The Body Tube should be short and of wide diameter.

The Stage.—A rack-work focusing movement should be provided. Levelling stages are a nuisance; specimens should be levelled in other ways. Mechanical movement is essential and rotation desirable.

The Vertical Illuminator.—The Beck or transparent illuminator is the only suitable form for high powers.

The Objectives.—Apochromatics are deficient in flatness of field, and the author questions whether good achromats are not to be preferred for photographic purposes, especially with the almost monochromatic colour screens now in use.

Mr. J. H. G. Monypenny contributed "Some Notes on the Metallurgical Photomicroscope."

The first part of the paper emphasizes the importance of the illumination in the production of a photomicrograph, outlines the conditions necessary for obtaining good illumination, and gives descriptions of

arrangements of condensers which fulfil these conditions. In connexion with the vertical illuminator, while the disc pattern is held to be superior to the prism, the faults of individual discs (owing to the unsuitable nature of the reflector) are pointed out. The influence of the curvature of the back combination of the objective on the production of flare is dealt with, and the differences found in achromats and apochromats mentioned. After a general discussion on the use of colour screens, the relationship of aperture and magnification and possible future developments in objectives for metallurgical work, the paper gives a description of apparatus specially designed for obtaining low-power photomicrographs embracing a large field of view. Some typical results obtained are included.

Mr. Leslie Aitchison, D.Met., B.Sc., A.I.C., and Mr. F. Atkinson read a paper on "Metallurgical Microscopes and their Development."

This paper is written from the point of view of the working metallurgist to whom the microscope is of constant value and usefulness; no attempt is made to discuss the subject from the optician's point of view.

Sir Robert Hadfield, Bart., D.Sc., D.Met., F.R.S., and Mr. T. G. Elliott, F.I.C., F.R.M.S., presented a paper entitled "Photomicrographs of Steel and Iron Sections at High Magnifications."

Further progress in metallography depends essentially on the use of more powerful microscopes giving higher magnifications allied with increased resolving power. To this end the authors have carried out an extensive research on steel and iron sections up to a magnification of 8,000 diameters. The paper is accompanied by eight plates containing twenty-six photomicrographs, the first two being selected from one of Sorby's earlier papers at nine magnifications, the remainder being obtained by the authors under various conditions at magnifications from 100 to 8,000. The type of apparatus required is dealt with and also the precautions necessary for exacting work of this nature, and it is shown in what directions further progress is to be anticipated.

Mr. F. C. Thompson, D.Met., B.Sc., contributed a paper on "The High-Power Photomicrography of Metals."

The paper aims chiefly at emphasizing the predominating importance of adequate resolving power for high magnifications. Starting with the fact that it is impossible to produce a microscopical rendering of a point other than as a disc, the diameter of which $=\frac{m\,\lambda}{2\text{N.A.}}$, where m is the magnification, λ the wave-length of light used, and N.A. the numerical aperture of the objective, it is shown how sorbite may become apparently laminated and how pearlite or sorbite may lose their structure, becoming apparently troostitic. The probable value of the use of ultra-violet "light" and silica lenses is pointed out. The "Davon" super-microscope is considered at some length, the conclusion arrived at being that whatever may be its merits in other directions it possesses little or no value for high-power photo-micrography as a result of the altogether inadequate resolving power.

Mr. Henry M. Sayers spoke on "Illumination in Micro-Metallography."

A full discussion of the subject of illumination is entered into. The author concludes that improvement is desirable in the following items:—

1. A transparent vertical illuminator reflector which shall get nearer the theoretical perfection of reflecting 50 p.c. and transmitting 50 p.c of the light incident on it at 45° without much coloration of the transmitted light. An optically worked glass lightly platinised seems the most promising.

2. A source of light of uniform and steady high brilliancy presenting an area of about half an inch square, to which a condenser of 2 in. working distance can be focused without damage from radiant heat. Either the "Pointolite" or the "half-watt" metal filament lamp may be able to meet this. The limitation of bulb size is important.

3. Oil immersion objectives intermediate in focal length and aperture between the $\frac{2}{3}$ in. and the $\frac{1}{12}$ in., well-corrected for colour. If anything can be done by computation to reduce glare by reflection from the lens surface in objectives designed for metallography it will be an advantage.

4. An auxiliary condenser combination with a long working distance compared with its focal length, to be used to present a magnified virtual image of the radiant to the objective.

5. A simple, firm optical bench or geometric slide arrangement with carriers for lamp and condenser at heights corresponding to those of usual microscopic axes when horizontal or vertical, to suit both positions.

Mr. Samuel Whyte, B.Sc., read a paper on "The Use of the Microscope in Engineering Works."

The microscope is of great practical use in controlling steel supplies and their heat-treatment. Its uses are briefly that of:—

1. Examination of raw materials, such as bars and especially small stampings for segregations and "laps" of oxide.
2. An aid to arriving at the best heat-treatment, especially for high-speed steels.
3. A means of detecting causes of failures, helping to work out the processes by which failures occur.

Professor H. Le Chatelier, in a communication, suggested some "Improvements in Metallurgical Microscopes."

It would be an advantage to try and obtain good photomicrographs with objectives corrected only for a single wave-length, say the highly actinic blue line of the mercury vapour lamp, instead of using costly apochromatics.

Great errors frequently arise from the ignorance of observers. Thus it is forgotten that every objective is intended to give an image at a fixed point. Another mistaken procedure is to reflect the luminous pencil by a total reflection prism, instead of by a mirror, forgetting that the objective is calculated for working in air, not glass.

Professor Carl Benedicks and Mr. Erik Walldow sent in a paper entitled, "Some Points Concerning Sharpness in High Magnification Micrographs."

The investigations were started as a detailed and critical examination of the new Reichert microscope, which is of the Le Chatelier type. It was found to produce excellent results at the very highest magnifications.

A note received from Professor F. Giolitti (Turin) suggested some "Alterations in the Design of the Le Chatelier Metallurgical Microscope."

The author considers this instrument preferable to other similar types on the market, but two disadvantages should be removed ; one is the sagging of the rack due to the weight of the stage, and the second is the absence of an apparatus for easily and rapidly changing the objective. An instrument is described which, while preserving the principle of vertical observation, embodies these improvements. The instrument can support on the stage several kilogrammes without causing distortion. The fine focusing is effected by manipulating not the stage, but the eyepiece tubes.

Mr. Albert Sauveur (Harvard University) also sent in a note suggesting "Improvements in Metallurgical Microscopes."

The two types of microscopes used in the United States are described. One of these is the horizontal-vertical type in which a vertical microscope is used for visual and a connected horizontal camera for photographic work. The author's magnetic holder for iron and steel is largely employed.

Mr. Sauveur does not expect much from greatly increased magnifications of iron and steel. What is needed at the moment are better methods for identifying constituents and impurities, and he briefly indicates the gaps in our present knowledge.

Mr. F. Ian G. Rawlins, F.R.M.S., described how an Ordinary Microscope can easily be Adapted for Metallographical Work.

The adaptions suggested are a focusing substage fitting, a simple carrier in which to mount the objective close to the reflector of the vertical illuminator, and for illumination a type of half-watt lamp made in Holland (used with a condenser of small aperture), in which the ring-filament gives a very solid and concentrated source of light.

Dr. W. H. Hatfield, in the course of the discussion, spoke of the value of high-magnification photographs of iron and steel, but he reminded the meeting that 1,000 diameters represented the limit of adequate resolution—more than that only enlarged the picture. If that resolution could be exceeded, he anticipated a considerable advance in knowledge. Such problems as the cause of the influence of cold work on metals still awaited solution.

Professor H. M. Howe, in a communication to the meeting, also indicated the value of aiming at higher magnifications.

Mr. E. F. Law similarly alluded to the fine structure of modern alloys, which could not be resolved with existing instruments. Similar

problems were to be found in the intercrystalline weakness of metal and the so-called amorphous phase.

A group of papers dealt with "Microscope Micrometry."

Mr. ZAY JEFFRIES (Cleveland, U.S.A.) communicated a paper on the application of the microscope to the determination of grain size in tungsten.

Professor W. M. THORNTON described a method of calibrating the eyepiece micrometer of a microscope used for measuring small objects, using a loose scale in the eyepiece in conjunction with a graduated slide for calibration.

Dr. A. E. H. TUTTON, F.R.S., contributed a paper on "The Grayson Rulings."

These wonderful rulings begin where others leave off, and they have reached an extreme value of 120,000 to the inch, representing the highest resolving power of the microscope. They are thus of great value in studying resolution, while the rulings of 40,000 to the inch (about the wave-length of red light) are capable of becoming of great importance in metrology and as fiducial marks in connection with interferometric fine-measurement in general.

The recent death of Professor Grayson in Melbourne was a great loss, and he hoped the meeting would help to ensure that his ruling machine should be available for the continued production of rulings.

A note by Professor H. LE CHATELIER described and illustrated "A Microscope used for Measuring Brinell Depressions."

Dr. H. HARTRIDGE, F.R.M.S., contributed a preliminary description of "An Accurate Method of Objective-testing," and Mr. F. TWYMAN a note on "The Testing of Objectives by Interferometry."

Mr. Hartridge's method aims at being less dependent on the skill of the observer than present methods. It consists in measuring with a micrometer the position of the image pattern when different parts of the objective aperture are used. If there is movement of the image pattern the micrometer reading is plotted against the N.A. of the aperture in use, and the resulting curve shows the aberrations present. Examples of typical curves obtained are discussed.

Mr. Twyman's method has not yet been much used, but actual tests made show on an interference "contour map" aberrations of wave surface not exceeding one wave length for monochromatic light. The interferometer employed is briefly described.

Lt.-Col. J. W. GIFFORD described how to make up simple "Light Filters for the Microscope and Photomicrography."

A solution of malachite green in glycerine is used which transmits only a broad band in the region of the F line and a narrow red band, and the latter is eliminated by the peacock-green glass used for making the cells for holding the solution. For photomicrography a solution of methyl violet is similarly used. The author's present method of making the cells is described.

AN ORDINARY MEETING

OF THE SOCIETY WAS HELD AT 20 HANOVER SQUARE, W., ON WEDNESDAY, JANUARY 21ST, 1920, MR. J. E. BARNARD, PRESIDENT, IN THE CHAIR.

The Minutes of the preceding Meeting were read, confirmed, and signed by the President.

The nomination papers were read of eight candidates for Fellowship.

New Fellows.—The following were elected Ordinary Fellows of the Society :—

Mr. Arthur S. Burgess, M.A., M.B., B.Ch.
Mr. Henry Herbert James Bull.
Mr. Harry Leon Gauntlett, M.R.C.S., L.R.C.P.
Mr. Albert Edward Mills, F.C.S., M.P.S., F.Z.S.
Mr. Venkata Rau, M.A., F.L.S.

A Donation was reported from :—

Major T. C. Squance, consisting of—

1. A Cuff Microscope.
2. A Culpepper and Scarlett Microscope.
3. Raspail's Modification of Cuff's Microscope.

On the motion of the **President**, a very hearty vote of thanks was accorded to Major Squance for his valuable gift to the Society.

THE ANNUAL REPORT of the Council for 1919 was read as follows :—

FELLOWS.

During the year 46 Ordinary Fellows have been elected, and 1 reinstated. Seven have died and 7 have resigned. One Honorary Fellow has been elected.

The number of Fellows on the Roll at the end of the year 1919 was as follows :—

Ordinary	420
Honorary	17
Ex-officio	69
Corresponding	1
	507

Of the Ordinary Follows—

334 have paid the annual subscription.
37 have compounded.
10 have had subscriptions remitted.

The deaths referred to above included that of Sir Frank Crisp, Bart., who for many years took a very active and important part in the work of the Society, and although he had not attended the Society's Meetings during recent years his interest in its welfare remained unabated.

Deceased Fellows :—

Sir Frank Crisp, Bart. Elected 1870.
Mr. John W. Dunkerley. Elected 1883.
Dr. George E. Fell. Elected 1882.
Sir Frederick Du Cane Godman. Elected 1877.
Mr. John Hopkinson. Elected 1867.
Mr. William Hudson. Elected 1864.
Mr. James A. Robertson. Elected 1908.

FINANCE.

The Council regrets that on account of the delay in issuing Part 4 of the Journal, it has again not been possible to get out the accounts in time for the General Meeting, therefore they will, together with the Treasurer's Financial Report, be presented later.

JOURNAL.

The Journal of the Society has been produced during the past year under somewhat difficult conditions, but it is hoped that as these adverse circumstances are gradually removed it will be possible to develop its scope and usefulness in many hitherto unexploited directions.

The Council wishes to thank most cordially the Editors, Abstractors, and Contributors for their valuable and much appreciated work during the past year.

LIBRARY.

During the year 95 volumes have been borrowed from the Library by Fellows of the Society, in addition to 21 volumes that have been obtained from Lewis's Library for their use.

Donations to the Library have been received from—The Macmillan Company, University of Chicago Press, Chapman and Hall, Limited, Dr. H. Woodward, British Museum, Lieut.-Col. F. K. McClean, and Mr. W. Carruthers.

INSTRUMENTS AND APPARATUS.

The Instruments and Apparatus belonging to the Society are in excellent condition.

During the year the Society has received the following donations:—

Mr. T. B. Rosseter:—Two Microscopes, Slide Cabinets, Slides, etc.
Sir David L. Salomons, Bart.:—A solid Silver Microscope, by François Watkins (1754).
Mr. Frank Rowley:—Case of Ivory Mounts.

Although no progress has been made with the Instrument Catalogue during the past year, the Council regards this as an important work which must now be vigorously prosecuted.

CABINET.

During the year further work has been done in connexion with the preparation of a card-index to the Slides belonging to the Society, and valuable additions to the Cabinet have been received from—Mr. G. H. Wailes, F.L.S., Mr. E. J. Sheppard, Mr. T. B. Rosseter, and Professor G. F. Bryan, D.Sc., F.R.S.

MEETINGS.

The Meetings of the Society have been well attended.

The papers have been of a varied and interesting character, and have been followed by useful discussion.

The **Biological Section**, which meets on the first Wednesday of each month, is most active and energetic, and its meetings are so well attended that the accommodation in the Library is barely sufficient for the purpose. During the session a visit was paid to the Laboratories of King's College, on the invitation of Mr. Barnard.

The thanks of the Society are due to Mr. J. Wilson for his continued energy and activity as Honorary Secretary of the Section.

METALLURGICAL SPECIMENS.

A collection of metallurgical specimens for microscopical study has been presented to the Society by Sir Robert Hadfield; and these specimens were prepared and polished at the Royal School of Mines through the kindness of Professor H. C. H. Carpenter.

A detailed report on the individual items included in this collection was read at an Ordinary Meeting by Mr. F. I. G. Rawlins, who has now been nominated by the Council for election as Curator of such specimens.

THE CONVERSAZIONE.

By the kindness of Dr. Walmsley, the Principal, and the Governing Body of the Northampton Polytechnic Institute, it was found possible to hold a Conversazione at that Institute in December last. This, the first since 1913, was highly successful. The exhibits were of a most interesting character, and particular mention must be made of the working exhibit, dealing with glass-grinding from beginning to end, by

students of the Institute, arranged by Mr. Redding. The good attendance of Fellows and their friends clearly indicates the great advantage that will be derived from the resumption of one of the principal annual fixtures of the Society.

The Council has tendered its best thanks to the Governing Body for placing the Institute at its disposal, and to the various gentlemen who contributed to the success of the gathering.

THE SYMPOSIUM.

The Report of your Council would not be complete without some reference to the Symposium which was held at the Rooms of the Royal Society on Wednesday last, January 14, for although the Symposium was not held until after the termination of the year to which this report relates, all the spade-work in connexion with it was carried out during the year under review, and some notice of the Symposium itself therefore fittingly finds place in this report.

In conjunction with the Faraday Society, the Optical Society, the Photomicrographic Society, and in co-operation with the Optical Committee of the British Science Guild, a Symposium and Discussion on "The Microscope: its Design, Construction and Applications," was arranged. It was probably one of the most important events that has occurred in the history of the Society, and the ultimate results cannot fail to develop and extend the influence of the Society in many directions. The bulk of the work of organization was undertaken by Sir Robert Hadfield and the President of this Society, Mr. J. E. Barnard, and our heartiest thanks are due to those gentlemen for their generous exertions which ensured the striking success of a unique function.

The best thanks of the Society are also due to the Council of the Royal Society for granting the use of the Rooms at Burlington House for the holding of the Symposium and the accompanying Exhibition.

Arrangements are being made for the publication of the papers read at the Symposium and a record of the proceedings.

Mr. Clemence moved, and **Mr. Heath** seconded, that the Annual Report be received and adopted. Carried.

Mr. Young moved, and **Mr. Marshall** seconded, that a very hearty vote of thanks be tendered to the Honorary Officers and Members of the Council for their services to the Society during the past year. Carried.

The President appointed Mr. Pledge and Mr. Taverner to act as Scrutineers, and afterwards announced the result of the ballot for the election of Officers and Council for the ensuing year as follows :—

President.—J. W. H. Eyre, M.D., M.S., F.R.S.Edin.

Vice-Presidents.—Sir George Sims Woodhead, K.B.E., M.A., M.D., LL.D., etc.; Frederic J. Cheshire, C.B.E.; Percy E. Radley; Alfred N. Disney, M.A., B.Sc.

Treasurer.—Cyril F. Hill.

Secretaries.—Joseph E. Barnard; David J. Scourfield, F.Z.S.

Council.—Maurice A. Ainslie, R.N.; Herbert F. Angus; Maurice Blood, M.A., F.C.S.; F. Martin Duncan, F.R.P.S.; Arthur Earland; Sir Robert Hadfield, Bart., D.Sc., F.R.S.; T. H. Hiscott; James A. Murray, M.D.; Julius Rheinberg; E. J. Sheppard; Charles Singer, M.A., M.D.; Joseph Wilson.

Librarian.—F. Martin Duncan, F.R.P.S.

Curators.—F. Ian G. Rawlins; E. J. Sheppard; Charles Singer, M.A., M.D.

A vote of thanks to the Scrutineers was moved from the Chair and carried.

The President then delivered his Presidential Address, entitled "The Present Status of Microscopy."

Commander Ainslie moved: "That the best thanks of this meeting be accorded to Mr. Barnard for his Presidential Address, and that he be asked to allow it to be printed in the Journal of the Society."

Mr. W. E. Watson Baker seconded the proposal, which was carried by acclamation.

Mr. E. J. Sheppard exhibited a slide showing mitosis in the root tips of *Fritillaria Imperialis*. The specimen was stained with safranin.

Mr. Scourfield exhibited living specimens of Hydrodictyon (Water Net). He mentioned that the specimens had been brought from the Caucasus, but it was also a British alga, although not very common.

The thanks of the meeting were accorded to Mr. Sheppard and Mr. Scourfield for their exhibits.

The President announced that the next meeting of the Society would be held on February 18, and of the Biological Section on February 4, when Sir Nicholas Yermoloff, K.C.B., K.C.V.O., would make a communication, "Notes on Beggiatoa and some Allied Forms."

AN ORDINARY MEETING

OF THE SOCIETY WAS HELD AT NO. 20 HANOVER SQUARE, W., ON WEDNESDAY, FEBRUARY 18TH, 1920, PROFESSOR JOHN EYRE, PRESIDENT, IN THE CHAIR.

The **Minutes** of the preceding Meeting were read, confirmed, and signed by the President.

The nomination papers were read of six Candidates for Fellowship.

New Fellows.—The following were elected Ordinary Fellows of the Society:—

Mr. H. V. Adams.
Mr. Alexandre Durand.
Prof. Alfonso Gandolfi Hornyold, D.Sc.
Dr. Maurice C. P. Langeron.
Prof. Samarendra Maulik, M.A., F.Z.S., F.E.S.
Mr. Charles Henry Oakden, F.R.P.S.
Mr. George Albert William Trinder, M.J.I.
The Rev. Canon G. R. Bullock-Webster.

Donations were reported from :—

The Cambridge University Press—
"An Introduction to the Study of Cytology."
Mr. E. Heron-Allen—
"Foraminifera of the Côte des Basques," and another volume.

On the motion of the **President**, hearty votes of thanks were accorded to the donors.

The **Financial Statement** for the year 1919, which should have been included in the Annual Report of the Council, was presented and read by the Treasurer, as here inserted (see pages 122–3).

FINANCE.

The Revenue Account shows excess of Income over Expenditure of £2 16*s.* 7*d.*

Part 4 of the Journal has not yet been issued, and the Council have therefore placed to reserve an amount of £150 to cover the cost of publishing this Number of the Journal.

Dr. INCOME AND EXPENDITURE ACCOUNT

Dec. 31, 1918. £ s. d.		£ s. d.	£ s. d.	£ s. d.
161 17 9	To Rent and Insurance . .			155 5 0
235 18 10	,, Salaries and Reporting . .			254 7 6
	,, Sundry Expenses—			
20 5 3	Library, Books and Binding		29 0 2	
86 10 11	Stationery, Printing, etc. .		85 19 7	
31 4 2	Petty Expenses and Postages		32 2 0	
				147 1 9
	,, Journal (Parts 1, 2, 3)—			
	Expenditure—			
	Printing	477 4 3		
	Editing and Abstracting .	60 1 6		
	Illustrating . . .	32 10 1		
	Postages, etc. . . .	23 12 0		
			593 7 10	
	Less Receipts—			
	Sales	343 19 7		
	Advertisements . .	88 15 7		
			432 15 2	
163 14 4				160 12 8
150 0 0	Reserve for Part 4 . .			150 0 0
	,, Conversazione			35 6 9
	,, Donation to Board of Scientific Societies			10 10 0
	,, Balance, being excess of Income over Expenditure . .			2 16 7
849 11 3				£916 0 3

Dr. BALANCE

Dec. 31, 1918. £ s. d.	LIABILITIES.	£ s. d.	£ s. d.	£ s. d.
	To Sundry Creditors—			
	Subscriptions paid in Advance		15 15 0	
	On A/c Journal Printing, etc.		160 19 3	
328 4 8	,, Sundries, Printing, etc.		37 8 4	
150 0 0	Reserve for Part 4 of Journal		150 0 0	
				364 2 7
	,, Life Membership (1917 A/c) .		63 0 0	
	Add Life Membership Fees received in 1919 . .		55 2 6	
63 0 0				118 2 6
	,, Capital Funds A/c—			
2140 13 1	Balance as per last A/c .	2140 13 1		
48 6 7	Reserve A/c	48 6 7		
	Excess of Income over Expenditure for year . .	2 16 7		
			2191 16 3	
	Less Depreciation of Society's Investments . . .		168 14 0	
				2023 2 3
2730 4 4				£2505 7 4

(Signed) C. F. HILL, *Hon. Treasurer.*
February 7, 1920.

Dec. 31, 1918. £ s. d.		£ s. d.	£ s. d.
	By Subscriptions (excluding Life Members' Fees)	636 0 11	
	,, for year 1919, unpaid . .	46 14 6	
634 1 1			682 15 5
67 4 0	,, Admission Fees		77 14 0
18 12 6	,, Sundry Sales and Receipts		35 15 8
106 1 7	,, Interest on Investments and Deposit A/c .		119 15 2
23 12 1			
849 11 3			£916 0 3

SHEET. Cr.

Dec. 31, 1918. £ s. d.	Assets.	£ s. d.	£ s. d.
	By Cash—		
300 0 0	On Deposit A/c	150 0 0	
53 14 4	On Current A/c	86 2 11	
1 16 4	On Petty Cash A/c	3 2 5	
			239 5 4
	,, Sundry Debtors—		
	Subscriptions unpaid	46 14 6	
	On A/c Journal Sales	183 7 6	
	,, ,, Advertisements . .	29 14 6	
210 2 2			259 16 6
	,, Investments at Valuation, Dec. 31, 1916—		
	£400 North British Railway 3 % Deb.		
	£500 Nottingham Corporation 3 % Deb.		
	£915 India 3 % Deb.		
	£150 Metropolitan Water Board 3 % .		
	£421 War Loan 5 %		
	£612 Caledonian Railway No. 1 Pref. .	1981 14 0	
	Less Depreciation	168 14 0	
1981 14 0			1813 0 0
18 16 0	,, Stock of Screw Guages, Valued at . .		18 16 0
	,, Property Account, as per last Balance Sheet	164 1 6	
	Add Purchased during year . . .	10 8 0	
164 1 6			174 9 6
2730 4 4			£2505 7 4

We have examined the accounts as above set forth, and have verified the same with the books, vouchers and securities belonging to the Society, and, in our opinion, the Balance Sheet is properly drawn up so as to exhibit a true and correct view of the state of the Society's affairs, but no account has been taken of the value of the Society's Library, Instruments and Stocks of Journals (valued for Insurance at £3000).

(Signed) T. H. Hiscott, H. H. Mortimer, } *Hon. Auditors.*

Since the last valuation of the Society's Securities, these have depreciated by £168 14*s*., and this amount has been written off the Investment and Capital Account.

The Investment Account therefore now stands at £1813.

The Auditors draw attention to the fact that the Property Account stands at the nominal amount of £174, and does not include any account of the instruments and books, which are insured for a sum of £3000.

During the year two Life Composition Fees have been received, and these have been placed to the credit of the Life Membership Account, making that Account £118 2*s*. 6*d*.

Compared with last year, the Income of the Society shows a steady increase, and the amount received from Subscriptions and Admission Fees is practically the same as received in 1913—the last pre-war year.

Unfortunately, the cost of publishing the Journal again shows an increase, and it will not be possible to revert to a bi-monthly issue unless the income of the Society is considerably increased.

Mr. Hill moved and **Mr. Wilson** seconded :—"That the Financial Statement be received and adopted." Carried.

Mr. Blood moved and **Mr. E. J. Sheppard** seconded—"That the best thanks of this Meeting be accorded to the Auditors, Mr. Hiscott and Mr. Mortimer." Carried.

The following papers were read by **Mrs. Arber, D.Sc., F.L.S.** :—"Studies on the Binucleate Phase in the Plant-Cell," by Agnes Arber; "On Multinucleate Cells: An Historical Study (1879–1919)," by Rudolf Beer and Agnes Arber.

These papers appear on pages 1–31.

The President said that the Society was greatly indebted to Mrs. Arber for her papers. As he was not a botanist he did not feel competent to deal with or criticize the papers, but he could appreciate the work, and realize the amount of tedious toil that had been necessary in their preparation.

Mr. E. J. Sheppard said that several facts had come under his notice. In rapidly growing tissues it was quite a common feature to see nuclei with very long pseudopodia. Sometimes they were extensiveiy lobed, and the ends extremely truncated or lobed. It had often occurred to him that these large pieces might be separated off. He had seen in these extended portions a nucleolus, and, as growth proceeded, it was quite possible they might form other nuclei. In cases like these he was inclined to suggest that it was amitotic division rather than mitosis.

Mr. Paulson pointed out that in the course of her remarks Mrs. Arber had supported very strongly the view that the irregular nucleus was a nucleus that was passing away, but admitted that there was a possibility that two nuclei might fuse within the cell. Mrs. Arber's view that the irregular nucleus was a nucleus in a state of old age, and Dr. C. R. McLean's that the bi-lobed nucleus was the result of the fusion of two nuclei, led to opposite conclusions. In the first case they had old age; in the second a form of rejuvenescence.

Miss Pankerd, Dr. Ruggles Gates and **Mr. Beer** also spoke.

Mrs. Arber, in reply, said there was a nuclear lobing that occurred in young cells, and, in addition, she had unfortunately used the word "lobing" for the irregular forms developed by very old nuclei. This perhaps accounted for the disagreement pointed out by Mr. Paulson. With reference to the nuclear pseudopodia breaking off, she would like to know whether Mr. Sheppard had evidence of their actual detachment. She had always found that they were joined by a little bridge. That was what had puzzled them. At the present time there appeared to be some doubt about most of the botanical cases described under the name "amitosis."

The President proposed a very hearty vote of thanks to Mrs Arber, and it was carried by acclamation.

Mr. Akehurst gave an exhibition of Professor Silverman's Illuminator for Opaque Objects.

Mr. E. J. Sheppard exhibited a slide showing Mitosis in Hyacinth root-tips, with marked differentiation in the staining of the chromosomes.

Mr. F. Martin Duncan exhibited a slide of *Cladonoma radiatum*, a Medusa narcotized by the Menthol Crystal method.

Mr. Wilson exhibited specimens of *Floscularia ornata.*

Mr. Scourfield exhibited a specimen of *Diaptomus Castor.*

Votes of thanks were accorded to the above for their exhibits.

The President announced that the next Meeting would be held on March 17, and the next Meeting of the Biological Section on March 3, when Dr. Tierney would read a communication on "The Bacterial Flora of Water."

The business proceedings then terminated.

REPORT ON THE WORK OF THE BIOLOGICAL SECTION OF THE ROYAL MICROSCOPICAL SOCIETY DURING 1918–19.

(*Read at the First Meeting of the Twelfth Session of the Section.*)

It is my pleasing duty at this Meeting to submit the Eleventh Annual Report on the Biological Section, which will show that the Section has not only survived the turbulent times through which we have passed during the last five years, but that it has steadily increased in membership and maintained the interest of its Meetings. The usual Meetings were held on the first Wednesdays of the months November to June, at which the average attendance was 25·6, as against the previous record of 22·4 for the Session 1916–17. At the February Meeting only nine Members were present, but these enthusiasts braved the snowstorm then raging, and the risk of having to walk to their homes owing to the strike of the railway employees then in progress.

The November Meeting was held at the King's College Laboratory, Chandos Street, on the invitation of our President, Mr. J. E. Barnard, who exhibited and described the various microscopical and optical apparatus used in his important researches on ultra-violet light, etc., and his assistant, Mr. Welch, gave a demonstration in staining bacteria.

At the Meeting on December 4, 1918, Mr. C. D. Soar gave a short description of "A Species of *Uropoda*."

The Meeting on January 8, 1919, was occupied by Mr. D. J. Scourfield, who described the "Sense-organs of *Daphnia* and its Allies."

Mr. A. W. Shepherd, on February 5, described the "Pollen-chamber of Cycads and its Function," and on March 5 Mr. F. Martin Duncan exhibited and described some interesting Marine Crustacea. The Meeting on April 2 was occupied by Sir Nicholas Yermoloff, K.C.B., who gave some "Notes on Flagellates," and by Mr. H. Taverner, who described "Colour-Photography as applied to Photomicrography." At the Meeting held on May 7 Mr. F. A. Parsons read some notes on a "Pycnogon," and Mr. N. E. Brown, A.L.S., made a communication on "Starch and its Formation." At the last Meeting, on June 4, Mr. E. J. Sheppard gave some notes on "Original Work on the Rat-Flea."

In addition to these more formal communications, many interesting specimens were shown under microscopes by the Fellows and described by them, and these formed very valuable topics for discussion which added greatly to the interest of the Meetings. J. Wilson.

ROYAL MICROSCOPICAL SOCIETY STANDARDS FOR EYE-PIECES.

During the year 1915 the Council of the Society deposited with the Director of the National Physical Laboratory their Standard Eye-pieces and Sub-stage Gauges.* These gauges were made for the Society in 1900, and were good examples of the Plug and Ring gauges of that date.† They have recently been carefully checked at the Natural Physical Laboratory, and are found to be not sufficiently accurate for use as standards. Furthermore, the Committee on Standardization of the Elements of Optical Instruments of the Department of Scientific and Industrial Research recommend that as the standards were for the eye-piece tube only, and the fit of the eye-piece was left to the maker's own judgment, it would be in accordance with advanced practice if suitable tolerances were defined and approved by the Society. This has accordingly been done, and the dimensions are shown in the following table :—

Eye-Piece Fittings—Diameters in Inches.

	Internal Diameter of Draw Tube.		External Diameter of Eye-piece.	
	Not under	Not over	Not under	Not over
Small	0·917	0·918	0·915	0·916
Large	1·270	1·271	1·268	1·269
Extra large . . .	1·410	1·411	1·408	1·409

The obsolete gauges have been returned from the National Physical Laboratory, and are now deposited in the Society's collection of instruments. It is worth while, however, recording the variation from the true nominal diameters of these old gauges. The N.P.L.'s report on them is follows :—

"The gauges have been measured at the Laboratory at 62° F., and the following table gives the dimensions :—

Nominal Diameter.	Mean of Plug Gauge.	Diameter of Ring Gauges.		Fit of the Plug in the Ring.
		Smallest value.	Value towards the faces.	
inches	inches	inches	inches	
0·9173	0·9167	0·91615	0·9166	Plug only enters a short distance at each face.
1·04	1·0393 to 1·03945	1·0393	1·0396	The plug can be forced through the ring with lubrication, but seizes at the centre of ring when dry.
1·27	1·2698 to 1·2700	1·26965	1·26975	As above.
1·41	1·40975	1·41005	1·41005	The plug is a nice fit in the ring.
1·527	1·52685 to 1·5270	1·52615	1·5265	The plug will not enter the ring.

* Trans. of the Royal Microscopical Society, 1915, p. 558.
† Ibid., 1900, pp. 141, 147.

"Four of the ring gauges are slightly bell-mouthed, and measurements have been made of the smallest diameter, which occurs towards the centre of the gauge, and also of the diameters towards the faces of the gauge. The latter measurements were made at about $\frac{1}{8}$ inch from the faces, and, therefore, owing to the taper, the diameters at the faces will be slightly larger than the values given. This is also evident from the fit of the plugs in the rings. In several cases the plug is found to enter a short distance at each face and then pull up well before the end of the plug has passed half-way through the ring."

The Council of the Society does not propose to have new standard reference gauges constructed for eye-pieces, as any maker can have, if he requires it, his own limit gauges checked at the National Physical Laboratory.

Attention is drawn to the fact that the Royal Microscopical Society's Standard Object Glass Screw Thread Gauges are still deposited with the National Physical Laboratory, and the Society has on sale special verified taps and dies for sizing the objectives and nose-pieces of microscopes.

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TRANSACTIONS OF THE SOCIETY.

III.—*On the Relationship between the Formation of Yolk and the Mitochondria and Golgi Apparatus during Oögenesis.**

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(*Read April* 21, 1920.)

One Plate and Four Text-Figures.

In this paper we have endeavoured to present some of the new aspects of the various questions surrounding the origin and formation of those elements or bodies which together form what is known as the "yolk" of the animal egg. So far as possible we have confined ourselves to the Vertebrata, but, as much of the newer work has been carried out on the oögenesis of the various Invertebrata, we have been obliged to refer to them rather often.

We have to discharge the pleasant duty of thanking Professor J. P. Hill, F.R.S., for reading over this paper and advising us, though he is not in any way responsible for any of the views we have expressed.

Cell Elements known to occur in Somatic and Germ Cells.

In all animal cells thoroughly studied by the modern technical methods, there occur two definite categories of protoplasmic inclusions—the mitochondria and the Golgi apparatus. In a previous

* Part of the material used in this research was supplied by a Government grant of the Royal Society, for which I express my thanks. (J. B. G.)

paper (*11*)* by one of us a special text-figure has been given, and the reader is referred to this.† On Plate II are figures of nerve, sperm, egg, liver and gut cells, to illustrate our views. Each cell when suitably prepared by either a Formalin-silver nitrate method, or an Osmic acid technique, shows a Golgi apparatus in an excentric juxta-nuclear position (Pl. II, figs. 1*b*, 2, 3, 4 and 9), or in a partly diffuse (Pl. II, fig. 1*c*), or a completely diffuse condition (Pl. II, figs. 1*a* and 5). Mitochondria are always found after the application of certain well-known techniques, and are shown in Pl. II, figs. 2, 3, 8 and 9 at M.

In growing eggs, or oöcytes of animals, one finds not only mitochondria and Golgi apparatus elements, but also various sorts of deutoplasmic materials—yolk, fat and glycogen.

Apart from the new structures which have been described within the cell cytoplasm, the modern technique has revealed at least one kind of granule or rod unknown hitherto within the nucleus (*36*). This new intra-nuclear body has been called a nucleolinus, and the recent observations of Carleton (*3*) have revealed the fact that the nucleolinus stains differently from the chromosomes, and is capable of independent binary fission. (See

* The italic figures within brackets refer to the Bibliography at end of the paper.

† Journ. R. Micr. Soc., 1919, p. 96.

EXPLANATION OF PLATE II.

Lettering.—GA = Golgi apparatus; A = acrosome; M = mitochondria; N = nucleus; NO = nucleolus; NL = nucleolinus; V = vacuole (glycogen); Y = yolk.

Scale of figures on right bottom corner of Plate.

Fig. 1.—Dorsal root ganglion cells of cat, to show at *a*, *b*, and *c* passage of Golgi apparatus from an excentric juxta-nuclear position (*b*) to a diffuse stage (*a*). Drawn from a Cajal preparation made by Dr. Penfield, Histology Laboratory, Oxford.

Fig. 2.—Spermatocyte of the cavy showing Golgi apparatus (compare with fig. 1*b*) and mitochondria. (Cajal followed by acid fuchsin.)

Fig. 3.—Spermatid of cavy showing Golgi apparatus, mitochondria, and acrosome. (Mann-Kopsch-Altmann method.)

Fig. 4.—Spermatocyte of *Limnæa* showing Golgi apparatus. (Kopsch's unmodified method.)

Fig. 5.—Oöcyte of *Limnæa* showing Golgi apparatus diffuse (compare with fig. 1*a*) and yolk bodies. (Same method.)

Fig. 6.—Metamorphosis of Golgi element to form a yolk body, as seen in Kopsch's methods (OsO_4). Not to scale.

Fig. 7.—Metamorphosis of mitochondrium into a yolk body, as seen in Altmann's method (acid fuchsin). Not to scale.

Fig. 8.—Binucleate liver cell of rabbit showing glycogen vacuoles and mitochondria (M). (Formalin and iron hæmatoxylin.)

Fig. 9.—Cell of mucous membrane of cat's duodenum showing Golgi apparatus (GA), mitochondria (M), nucleolus (NL), and nucleolinus (NO) stained black. From a preparatiou by Cajal's method, with safranin, made by Mr. H. M. Carleton. Histology Laboratory, Oxford.

Fig. 10.—Oöcyte of *Limnæa* by Altmann's method; mitochondria red, yolk brownish.

Pl. II, fig. 9, NO.) Thus the cell, as the modern cytologist knows it, is a truly complicated structure, and the revelation of so many new bodies within it may necessitate the reconsideration of many biological conceptions.

Among certain writers, of whom Fauré-Fremiet (*10*) may be taken as an example, it is considered that the structure which others consider to be a Golgi apparatus is produced at one period of the life of the cell by a metamorphosis from part of the mitochondrial constituents of the cytoplasm. Fauré-Fremiet states that the "Nebenkern" rodlets or dictyosomes of the snail spermatocyte are produced by a transformation of mitochondria. The dictyosomes of the snail spermatocyte are the representatives in that cell of the Golgi apparatus, and we cannot therefore regard them as having anything to do with the mitochondria. Hirschler (*22*) and one of us (*16*) have shown that the dictyosomes or Golgi rodlets can be traced through development. Fauré-Fremiet's work was repeated by one of us (*16*), and it was shown that by the Kopsch or Cajal methods the dictyosomes are found to be present in the youngest germ cells and are not directly related to the mitochondria. Following his previous views on the "Nebenkern," Fauré-Fremiet in his work on Ascaris seems to misinterpret the Golgi apparatus of this form.

The following table shows the elements which have been hitherto mentioned:—

- Oöcyte
  - Nucleus
    - Chromosomes.
    - Nucleoli.
    - Nucleolini.
  - Cytoplasm
    - Mitochondria.
    - Golgi elements.
    - Yolk granules.
    - Fat or lipoid vacuoles.
    - Glycogen.
    - Chromatin granules.

Explanatory Remarks on Methods.

Elsewhere (*11*) one of us has noted some staining reactions of yolk, fat, mitochondria and Golgi apparatus. In order to make this paper clear it is proposed to describe shortly the methods used, and some of the staining and fixing reactions of the various cytoplasmic inclusions.

Nearly every fixing mixture contains either alcohol or acetic acid, but the last few years of cytological research have shown that the picture given by a fixing mixture containing them is incorrect and inadequate, and one cannot fail to be surprised at the improvement produced when these reagents are omitted. Nearly all the modern research on the cytoplasm has to be carried out by

observers using chrome- or platinum-osmium fixatives, followed by iron-alum hæmatoxylin, Benda's crystal violet, or Altmann's acid fuchsin; or by the useful methods of Cajal or Golgi, which consist of silver-nitrate impregnation following formalin fixation. Intra vitam methods, such as Janus green, neutral red, or Dahlia-violet are also used extensively. The mitochondria are extremely fuchsinophile, and after chrome-osmium fixation stain in an intense manner in iron-alum hæmatoxylin. The Golgi apparatus of somatic cells and of ovarian cells rarely stains by these methods (Altmann or Haidenhain), although the Golgi apparatus of the male germ cells nearly always stains in fuchsin or hæmatoxylin after chrome-osmium fixation.

To demonstrate the Golgi apparatus of somatic cells, or of oögonia or oöcytes, there are several methods; the silver-impregnation methods of Cajal or Golgi are useful, especially the former, and in the hands of an experienced technician are fairly reliable; then there are the methods of Kopsch and Sjövall, which have as their basis osmium tetroxide. Modern improvements on the Kopsch method are those of Mann-Kopsch (*18*), and Mann-Kopsch-Altmann (*11*).

On Pl. II we endeavour to give true pictures of the appearance of various cells, after treatment of a tissue or organ, by means of one of the above-mentioned special methods. In figs. 1, 2, and 9 we have cells impregnated by a formol-silver method; in figs. 4 and 5 the material has been stained by Kopsch's method, and in figs. 8 and 10 by iron-hæmatoxylin and acid fuchsin respectively.

To a greater or less extent most of these modern methods can be controlled in such a way as to stain any given category of cell body in a perfectly specific manner, though, as will presently be noted, puzzling exceptions may be met with. It can be said, however, that a cytologist can generally distinguish between or stain specifically—yolk, fat, glycogen, chromatin, mitochondria, and Golgi apparatus.

The problem, nevertheless, becomes very complicated when it is found that one sort of cell granule or element may metamorphose into, and become chemically altered to resemble another.

Nomenclature and Definitions.

Archoplasm, Archoplasmic Sphere.—A concentrated region of the cell cytoplasm generally associated with the centrosome, and at certain stages with the Golgi apparatus elements. The archoplasm seems to have some relation to the amphiaster, but this has not been conclusively established. The sphere or archoplasm is also known as the idiozome (Meves) (*29*), or, as it is sometimes wrongly spelt, "idiosome."

Chondriome means the entire mitochondrial content of the cytoplasm, or the mitochondrial apparatus or complex looked upon as a whole. This does not include the Golgi apparatus.

Chromidium.—A granule or structure formed of substance resembling the chromatin of the nucleus in its microchemical reactions. It is well preserved in alcohol-acetic fixation, and stains in basic dyes like methyl green and safranin; it will not impregnate in Cajal or Kopsch techniques (*11*), and goes blue or green in Champy-Kull's method (*18*), or green in Bensley Cowdry (*18*).

Chromatic.—Used to describe any granule or structure which stains heavily in any dye (also chromophile).

Chromatinic.—Used to describe any granule or structure whose microchemical characteristics are so similar to those of the chromatin of the normal nucleus as to lead to the belief that it is formed of chromatin.

Chromophobe.—Used to describe any structure which does not stain by the usual methods.

Cytoplasmic Inclusions refers to any granules or rods included within the cell cytoplasm; these may be classified under two subheads as follows:—

(*a*) *Protoplasmic Inclusions* refers to granules belonging to either mitochondria or Golgi apparatus, or to isolated granules known to be formed of protoplasm (e.g. chromatoid body of cavy spermatids).

(*b*) *Deutoplasmic Inclusions* refers to inert non-living granules, such as fat, glycogen, or yolk, which are incapable of binary or multiple fission, and which are not centres of cytoplasmic activity in the same way as the protoplasmic inclusions.

Deutoplasmagenesis is the process of formation of yolk spheres or discs, fat, and glycogen within the egg during oögenesis. It only includes the evolution of the mitochondria and Golgi apparatus so far as they are directly concerned with the formation of either yolk, fat or glycogen. (Also *Vitellogenesis.*)

Golgi Apparatus.—This phrase was originally used for the internal reticulate apparatus in the cells of nerve tissue prepared by a formalin-silver nitrate technique. It is found, however, that other somatic cells of all kinds, as well as germ cells, contain an apparatus which exhibits the same microchemical reactions and morphological arrangement as the Golgi apparatus in the nerve ganglion cells. The Golgi apparatus has the following reactions:

1. Black in Cajal's, Da Fano's, or Golgi's special formalin (uranium and cobalt nitrate, or arsenious acid) silver nitrate impregnation methods (*11*).

2. Black in Kopsch's or Mann-Kopsch's osmium tetroxide methods (*18*).

With regard to the use of the word Golgi apparatus, it is necessary to point out that in young germ cells and in all embryonic cells the apparatus occupies a position surrounding the archoplasm and centrosome, from which the elements of the apparatus are rarely separated. The word Golgi apparatus we take to mean all the Golgi elements or dictyosomes (Perrincito, *33*) en bloc; the words Golgi element or dictyosome refers to a part of the apparatus lying discrete.

For a much fuller treatment of the subject, see the following papers (*11–20*, *21–24* and *32*) in the bibliography; also note the microchemical reactions explained on pages 129 and 135 of the present paper.

Mitochondria.—Numerous grains or filaments scattered in the cytoplasm, which act as follows:—

1. Redden in acid fuchsin after bichromate of potash and osmic fixation (*11*).

2. Stain violet by Benda's method, red by Champy-Kull, and black in iron-hæmatoxylin after neutral formalin or chrome-osmium fixation.

3. Do not go black but red after Mann-Kopsch-Altmann, or Kopsch-Altmann; do not stain after Bouin or corrosive acetic, or Petrunkewitsch or Carnoy fixation, followed by Ehrlich's hæmatoxylin or methyl-blue eosin (etc.).

4. Stain intra vitam in Janus green and neutral red (*18*).

5. Either do not stain, or are only golden brown or greyish, after Cajal's silver-nitrate method. (For further details see *4*, *9–24*, *31*, *35*, and *42*.)

Yolk.—The word has been applied to any granular formations of the cytoplasm of the egg. This usage must be abandoned, for recent researches show that certain granules hitherto called yolk are really true mitochondria, similar to those of ordinary somatic cells. The egg contains yolk and mitochondria and Golgi apparatus, the yolk being something different from the two latter protoplasmic inclusions. It seems certain that part of both mitochondria and Golgi elements can change into yolk; this makes it difficult to give a simple definition of the word. In any given species one could easily draw up a table distinctly showing the differences between yolk and protoplasmic inclusions such as the mitochondria; but such a table would not apply to every other species, because the yolk in eggs of different species, even in closely allied forms, may vary greatly in its chemical constitution and origin.

The main constituents of the yolk of the hen's egg, which has been carefully examined, are protein, fat and lipin, and there is little doubt that the true yolk of invertebrate eggs also consists of protein, fats, and lipins, though not necessarily in the same percentage.

While typical yolk spheres will be found to consist of these

Method	Cajal	Kopsch Series	Chrome-Osmium & Iron Hæmatoxylin (or Altmann)	Bouin & Corrosive Acetic & Ehrlich's Haematoxylin.	Champy-Kull.
MITOCHONDRIA .	Either do not show, greyish or golden brown. (See Pl. II, figs. 2 and 9.)	(See Pl. II, figs. 3, 4 and 5.) Often will not show, or faintly yellowish, more rarely black or brown, but can often be decolorized rapidly in turps.	Black (or red). (See Pl. II, figs. 8 and 10.)	Do not show.	Red.
GOLGI APPARATUS	Black. (See Pl. II, figs. 1, 2 and 9.)	Black, and resists decolorization in turps longer than mitochondria, fat or yolk.	Rarely shows, when it does, black (or red). (See Pl. II, figs. 8 and 10, not stained.)	Does not show.	Rarely shows, if so, red.
YOLK GRANULES	Either will not show, greyish or golden brown.	Yellowish, or black easily decolorized in turps. (See figs. 5 and 10.)	May or may not go black (or unstained very rarely red).	Not stained, or yellowish.	Yellowish or black.
FAT VACUOLES	Do not show.	Black, easily decolorized in turps.	Black in unstained preparation (or black).	Not stained, washed away.	Black.
CHROMATIN GRANULES	Do not show, but may subsequently be stained in a basic colour, like methyl green or safranin.	Yellowish, will subsequently stain in hæmatoxylin or safranin.	Black to grey (or reddish purple).	Bluish to purple.	Blue.

three categories of substances, it is possible that any one of the categories may be either absent or reduced to a very small quantity. Thus the yolk of the sponge egg seems to contain a very slight amount of protein, as is indicated by fixing and staining tests. As has already been mentioned, the percentage and kind of fat may vary also, even among closely allied forms. Many workers now consider that the mitochondria are formed of a protein substance associated with a lipin, and microchemical tests appear to bear out this assumption. The constitution of the Golgi apparatus is probably much like that of the mitochondria—i.e. proteid in some way linked with lipin materials.

Any collection of granules or discs within the egg cytoplasm which behaves according to a majority of these tests may be called "yolk":—

1. Granules which do not go red in Altmann, Champy-Kull or Bensley-Cowdry (i.e. granules which are not fuchsinophile). In the case of Champy-Kull, grains which go blue, or in the case of Bensley-Cowdry grains which go green, are likely to be chromatin. (Insect yolk, however, may be fuchsinophile.)

2. Granules which are yellowish, brown or black in Champy-Kull, Benda, or chrome-osmium fixation, i.e. Flemming or Hermann's fluids.

3. Granules which do not go black after staining in iron-hæmatoxylin, following two days' fixation in neutral (5 p.c. to 20 p.c) formalin. (There are notable exceptions to this, e.g. the yolk of Amphibia, which stains intensely in iron-hæmatoxylin.)

4. Granules which do not disappear after fixation in corrosive acetic acid, Bouin, Carnoy or Petrunkewitsch. (These are many exceptions to this, e.g. the delicate yolk of sponge, and some mollusc eggs.)

5. Granules, which rarely go black in Mann-Kopsch or Kopsch (but which, if they do go black, are easily decolorized by a short immersion in turpentine, and are then left as yellowish spheres, and not as vacuoles); granules which will not stain red after such extraction of their colour in turpentine.

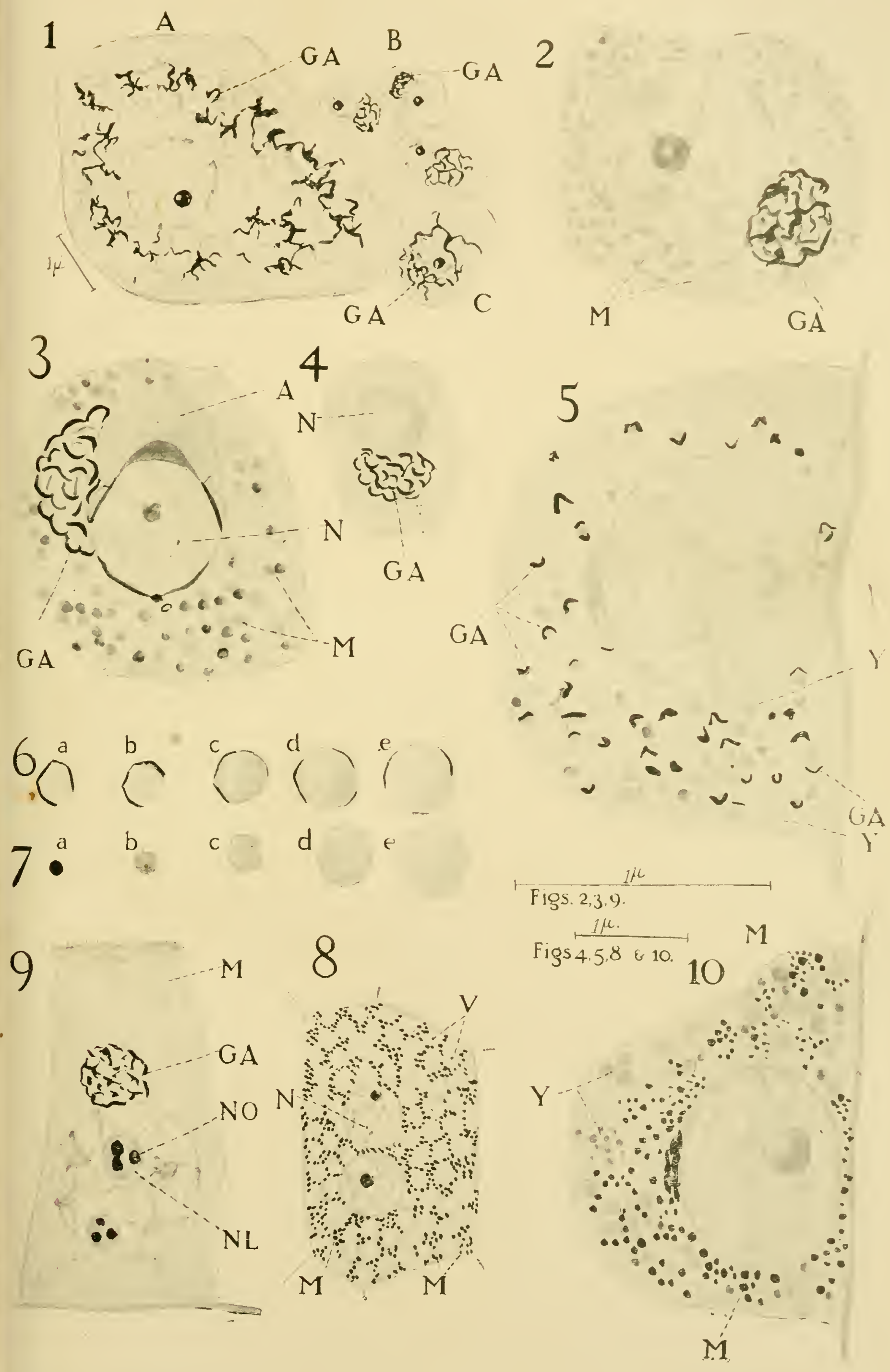
6. Granules which are greyish or yellowish intra vitam (in some cases, however, the mitochondria may be loaded with a yellow pigment).

7. Granules which do not go black in Cajal's silver impregnation method.

8. Granules which exceed 2μ in diameter.

Yolk-Formation in the Sponge Grantia.

Recently the oögenesis of *Grantia compressa* was studied by one of us *(19)*. At no period of oögenesis will the usual techniques,


1
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9
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which demonstrate the mitochondria of the sponge egg, bring into (so called chromidia) evidence the yolk spheres. In no form could one feel more certain that the yolk spheres are not metamorphosed mitochondria. The yolk granules of *Grantia* are formed in and by the ground cytoplasm, and are of a much more delicate nature than the true mitochondria. The latter, in sponge eggs, are so large and so few, that there can be no question of confusion of yolk spheres and mitochondrial spheres at any stage of oögenesis.

So far as could be ascertained the yolk spheres of the *Grantia* egg are of a semi-fluid consistency, and possibly contain a small amount of protein, but a large bulk of lipin. The spheres are believed to arise as small vacuoles in the ground cytoplasm of the endoplasm of the egg. Techniques which depend for their efficiency on the coagulation of protein are quite inadequate for the preservation of the sponge yolk, while methods known to fix fat or lipins are the only ones suitable for the yolk of the *Grantia* oöcyte. The spheres in the *Grantia* oöcyte do not go black in osmic acid, even after prolonged immersion in strong solutions.

Oögenesis of Mollusca (Helix and Limnæa).

As a simple type the oögenesis of a mollusc (*Limnæa*) may be taken. Lately it has been shown (*16*) that the ripe egg contains three categories of granular or formed structures, viz. mitochondria, Golgi elements and yolk spherules. The mitochondria and Golgi elements appear to be present in the germinal epithelial cells, though it has been difficult to make certain with regard to the mitochondria; it is however a fact that in Amphibia (*Rano, Bufo, Molge*), Birds (*Gallus*), Mammals (*Mus, Lepus*), in other Mollusca (*Helix, Arion*), in Insecta (*Apanteles, Sphinx*), the primitive germinal cells contain mitochondria and Golgi apparatus.

It has been shown that in such a mollusc as *Helix* or *Limnæa* the mitochondria and Golgi elements gradually spread out throughout the oöcyte, and the grains forming these systems increase in number. It seems quite probable that the diffuse Golgi elements actively take part in the formation of yolk bodies, as indicated in Pl. II, fig. 5; we cannot say so much in the case of the mitochondria. From a study of a number of Pulmonate Mollusca we have concluded that much of the evidence in these forms is against the view that part of the mitochondrial constituents of the cytoplasm metamorphose into yolk. The latter seems to form either from Golgi elements, or per se in the ground cytoplasm. Since we cannot yet give a definite opinion on this point, we have taken care to leave the matter open in our schemes of oögenesis given on page 148 of this paper.

Oögenesis of the Mollusc Patella.

Patella is the common sea-limpet; a study of the oögenesis of this mollusc shows that the formation of the yolk is a more complicated process than is the case with another mollusc such as *Helix* (the snail) or *Limnæa*. Just as in *Helix* the youngest oöcytes contain a typical Golgi apparatus formed of discrete rods (dictyosomes) and a group of mitochondria. While in *Helix* the Golgi apparatus spreads out through the egg cytoplasm, and becomes an important contributor to the number of formed bodies of the egg, the Golgi apparatus in *Patella* is from the first beginning of deutoplasmagenesis a much more important part of the two protoplasmic inclusions (mitochondria and Golgi apparatus). Not only do the Golgi elements surpass the mitochondria in their growth activities, but many of them become associated in some way with the yolk spheres. This is to say, that however the yolk spheres may be formed, be it from the mitochondria, archoplasm, or simply in the ground cytoplasm, the Golgi elements later become stuck upon the surface of many, if not all, of the yolk spheres, and form a most important part of the yolk substance.

The important point to note is that in two molluscs, *Helix* and *Patella*, the Golgi apparatus in each case differ a good deal in the extent in which they take direct part in the formation of true yolk bodies. We believe that in the case of *Patella* the Golgi apparatus provides most of the yolk spheres of the full-grown egg, but in *Limnæa* either the mitochondria (or the ground cytoplasm) are most active in this respect.

In Pl. II, figs. 6 and 7, we have given figures representing the staining changes which come over the Golgi element (stained with OsO_4) or the mitochondrium (stained in acid fuchsin after chrome-osmium fixation) during their metamorphosis into yolk bodies.

Oögenesis in Amphibia and Insecta.

In some ways the oögenesis of Amphibia typified by *Rana* or *Triton* (Molge), and of Insecta by *Apanteles* and *Dytiscus*, presents the same general features. The mitochondria increase in number and tend to form a filamentous mass on the peripheral part of the growing oöcyte. When deutoplasmagenesis begins the yolk discs appear at the periphery of the egg, in the mitochondria, but though the mitochondria may lie towards the centre of the oöcyte, or entirely spread throughout the oöcyte, the yolk discs appear at the periphery. We have observed this also in the oöcyte of the sparrow (*Passer domesticus*).

Note.—(1) The yolk discs of insects and amphibians appear at the periphery of the egg where mitochondria happen to lie; and

(2) yolk discs do not appear in the inner regions of the egg till later, even though these regions may contain abundant mitochondria.

It seems natural to conclude that the yolk grains of the egg are formed from metamorphosed mitochondria, as is believed to occur in other animals. It should be mentioned that in both insects and amphibians the mitochondrial elements become so fine that it is difficult to tell whether the yolk is being formed from them or not.

In preparations of frog ovary by the Mann-Kopsch method (*18*) the mitochondria of the oöcyte impregnate in a different manner from the yolk, and no certain transitional forms between the mitochondria and the yolk can be noted. We consider that the matter is not settled.

By the Mann-Kopsch method the full-grown frog oöcyte cytoplasm is found to contain enormous numbers of granules which fall into three categories, according to the manner in which they act in the osmium tetroxide. There are, firstly, fine evenly sized grains which go brownish to black; these have been identified as the mitochondria. There are, secondly, the very large yolk bodies, which go yellowish; then one finds intermediate forms which go black in the osmium solution. These granules intermediate in size may be derived from, and represent, the Golgi apparatus of the frog oöcyte. Sufficient work on this problem has not been carried out to enable us to make quite certain as to the identity and origin of the intermediate or black granules, and as to whether the large yolk granules and the smaller mitochondria are in any way related to the black granules.

The granules, hitherto called "yolk," are in the case of the frog oöcyte of at least three different kinds, whose histo-chemical reactions are different in each case.

About twelve years ago Lams (*27*) carried out some work on the formation of the "vitellus" of the amphibian egg. Lams used no Golgi apparatus method, and he did not go very deeply into the question as to whether the mitochondria metamorphose into yolk. In the oögonium Lams finds an archoplasm containing a centrosome and surrounded by a halo of mitochondrial substance. During growth the mitochondria multiply with the archoplasm as their centre, so that the former become surrounded by a thick mass of mitochondria. The archoplasm Lams calls the yolk body (corps vitellin), and the mitochondrial cloud he calls the yolk-forming mass (masse vitellogène), believing that the mitochondria of the frog are in some way connected with the formation of the yolk.

We have gone into the subject of the behaviour of the mitochondria in the oögenesis of the Amphibia. What Lams describes with regard to the evolution of the mitochondria is in

accordance with our own observations; but we differ as to interpretations. The archoplasm has no direct connexion with the formation of the yolk, though we recognize that it is in the region of the archoplasm that the mitochondria are found and grow most rapidly; this however does not allow us to conclude that the archoplasm may be called a vitelline body, or that it grows or behaves in a way which resembles the true yolk nucleus of an Ascidian. While we acknowledge that the mitochondria form an elongate matted body in the region of the archoplasm, during one period of the oögenesis, it is extremely doubtful whether this body should be homologized with the Ascidian yolk nucleus. We conclude that there is not satisfactory evidence that a true "yolk body" or "nucleus" exists in Amphibia.

This temporary conclusion is in agreement with the view expressed by Dubuisson (*7*), with whose work Lams disagrees.

In insects such as *Stenobothrus*, the Golgi elements appear to be separate from the yolk. In *Dytiscus*, Nusbaum-Hilarowitz (*31*) has shown that the Golgi apparatus and the formation of yolk spheres are unconnected with each other. In *Dytiscus* with Champy-Kull's method the yolk spheres are fuchsinophile (see page 136). We have lately seen some of Mr. L. Hogben's preparations of *Periplaneta* ovaries, from which it seems clear that some, at least, of the yolk spheres of the cockroach egg are formed within the nucleus, possibly from the nucleoli, and finally shot out into the egg cytoplasm.

Formation of Yolk in Ascidian Oögenesis.

According to Hirschler (*22*) yolk granules of Ascidian ova are formed by two processes:—

(1) A simple metamorphosis, and enlargement of the mitochondrium to form a new body, and (2) a secondary fusion of many of the Golgi elements with these swollen mitochondria, to form a compound structure, and a swelling up of the Golgi elements themselves.

He tells us "that the yolk spherules which represent the reserve material of the developing embryo consist of mitochondrial and Golgi apparatus substance. During embryonic development a more vigorous growth and regeneration of the apparatus, and perhaps of the mitochondrial substance, also very probably takes place, as the investigations of Van der Stricht on *Noctula* would suggest. This regeneration would, as we suppose, come about in the following manner:—The yolk gives off the apparatus and mitochondrial structures present in small quantity in the dividing egg cell, so that the dissolution and using up of the yolk during embryonic development would thus in great part be attributed to the giving off of these substances."

Thus Hirschler thinks that the swollen mitochondria (i.e. yolk) may shrink to their original size during the development of the egg, and so again come under the category of mitochondrial substance.

Oögenesis of Ascaris.

Hirschler (*21*) finds a Golgi apparatus and mitochondria in the young oöcytes of *Ascaris*. The mitochondria occasionally swell up to form the large yolk granules of the older eggs. The Golgi apparatus segments may lie close to the yolk spheres, but do not generally become intimately associated with them. The mitochondria and Golgi elements are throughout separate entities. Hirschler also describes true fat granules in the ground cytoplasm. His interpretations may be graphically shown thus:—

ASCARIS.

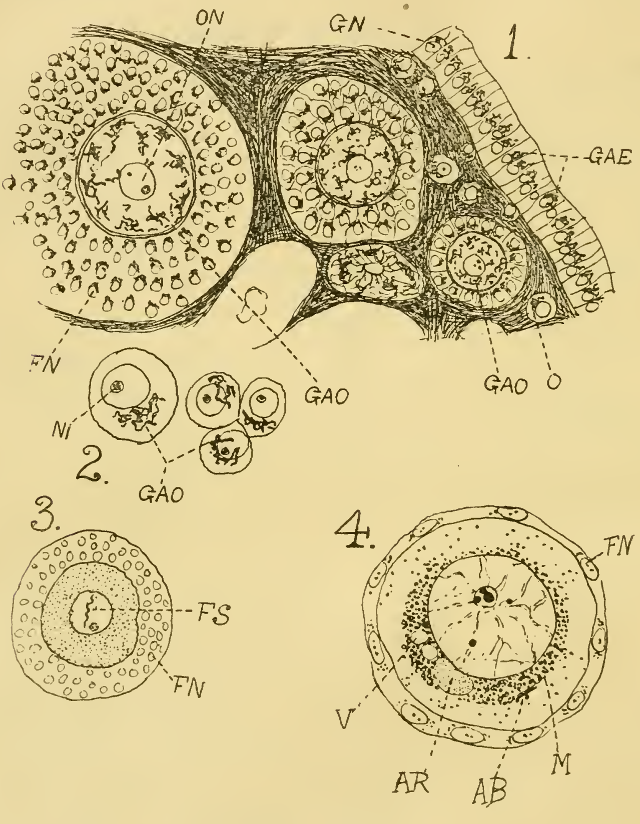
Oögonium.		*Full-grown Oöcyte.*
Mitochondria	→	Definitive mitochondria.
	→	Yolk spheres.
Golgi apparatus	→	Golgi apparatus.
Ground cytoplasm	→	Fat vacuoles.

Subsequently to Hirschler's observations, Fauré-Fremiet carried out an exhaustive research on *Ascaris* (*10*). Fauré-Fremiet did not seem to have known of Hirschler's work, and the interpretations of the former author cannot be accepted completely by us. Fauré-Fremiet describes the young oöcytes as containing mitochondria (chondriokontes), vacuoles of phosphate substance, and fat-globules. He recognizes no Golgi apparatus. He says: "As have been explained above, a part of the chondriome (mitochondrial constituents of the cytoplasm) of the oöcytes of *Ascaris* become transformed into special elements comparable to certain 'Nebenkerne.'" Fauré-Fremiet here means the "nebenkern" of the snail spermatocyte, which we know now to be a true Golgi apparatus—see Perrincito (*33*) and (*16–20, 20–4,* and *42*). Hirschler (*21*) previously showed that the Golgi apparatus (or "nebenkern") of *Ascaris* is not related to the mitochondria. Fauré-Fremiet is wrong in his interpretation of these elements in the *Ascaris* egg, and we prefer Hirschler's interpretation.

The Golgi Apparatus of the Mammalian Ovary and Testis.

The cells of the mammalian ovary, like those of invertebrate ovaries, contain a typical Golgi apparatus, demonstrable either by

Cajal's method, or by the Mann-Kopsch method. (Text-fig. 1, Del Rio Hortega (*36*), which shows the apparatus in the oöcytes, follicle cells, and germinal epithelium of the rabbit and cavy (fig. 2).)



Text-Figures 1, 2, 3, 4.

Fig. 1.—Part of the ovary of the rabbit prepared by Cajal's Golgi apparatus method, showing the apparatus in the germinal epithelium (GAE), and in oöcytes at different stages: O, GAO, GAO. At O is a very young oöcyte showing the Golgi apparatus in its excentric position; in the oöcyte at ON the follicle (FN) is well formed, and each nucleus has a Golgi apparatus outside it; the oöcyte is surrounded by a zona pellucida, and the apparatus consists of branched threads lying through the cytoplasm (GAO). After Rio Hortega (*36*).

Fig. 2.—Young oöcytes of the guinea-pig, drawn at a higher magnification to show the Golgi apparatus at GAO, and the nucleolinus (?) at NI. After Rio Hortega.

Fig. 3.—Oöcyte of *Canis*, showing inside the nucleus the "filament spiroïde intranucleaire," which may be another form of the nucleolinus (page 130, and compare Pl. II, fig. 9, NO); FN = follicle. After Rio Hortega.

Fig. 4.—Young oöcyte of man, showing the mitochondria (M), the archoplasm at AR, vacuoles at V, and the enigmatic rod-like body at AB. FN = follicle. After Marie Loyez (*28*).

In the oöcyte the apparatus is at first juxta-nuclear and eccentric, but later spreads out throughout the egg cytoplasm. The elements of the Golgi apparatus are somewhat filamentary and branched, and possibly take no direct part in the formation of fat or yolk. From our preparations of guinea-pig testis, both by Cajal and the Mann-Kopsch methods, we believe that the mammalian Golgi apparatus, like that of certain invertebrates, consists of numerous semi-lunar plates or rods and not of branched straight bodies as drawn by Hortega. The appearance shown in Text-figs. 1 and 2 of such branched rods is possibly due to the distortion caused by the formalin fixation. In all probability further work will show that the Golgi apparatus in mammalian oöcytes is formed of small curved plates and rods which may occasionally join together in chains to produce a reticular or branched appearance. In Pl. II, figs. 2 and 3, are a spermatocyte and a spermatid showing the Golgi apparatus (GA).

On the Supposed Metamorphosis of Mitochondria into Fat Vacuoles.

Dubreuil (*8*) and Murray (*30*) showed that mitochondria could metamorphose into bodies possessing the histo-chemical reactions of fat. The elongate mitochondrium in this case becomes swollen parts of its length, and finally forms one or more separate fat spheres. It may be remembered that in degeneration of medullated nerve, the lipin substances in the sheath become changed into fat. The fat globules which appear in mammalian and other oöcytes during oögenesis may be formed partly by a metamorphosis of the lipin substance in the mitochondria, but it would be a mistake to consider that the fat of cells is exclusively produced by changes in mitochondria.

In the case of digestion there seems little doubt that the mitochondria take no direct part in the production in the cells of fat. Food matter containing the latter is acted upon by a lipase which breaks up the fat into glycerol and fatty acid, in which form it passes through the membrane of the intestines, in whose cells it is reconverted into fat. Such fat ultimately becomes distributed by the blood, and is taken up into connective tissue and other storage cells. There seems no reason for disbelieving that oöcytes could take up fat in a similar manner, and independently of the mitochondria.

With reference to the formation of fat in cells, we may give some account of Schreiner's work on the subcutaneous cells of Myxine (*39*). He describes a most complicated process in these cells; their nuclei contain a nucleolus or several nucleoli, which bud off smaller bodies, and these become separate as "neben-

nucleolen." These secondary nucleoli pass through the nuclear membrane into the cell cytoplasm, and ultimately give rise to chondriokontes or plasma rodlets. The latter appear to be true mitochondria, and soon segment to form "secondary granules," which swell up to form fat globules. The latter part of this account agrees fully with the work of Murray and Dubreuil, but the former part—i.e. that referring to the formation of the secondary nucleoli and their passage into the cell cytoplasm—has not yet been confirmed by other observers. We should like to know whether the subcutaneous cells before their metamorphosis into fat cells do not already contain mitochondria.

It should be noted that Schreiner has used the latest cytological methods, and for this reason alone his views demand attention. (See p. 154.)

The Archoplasm and the Formation of Yolk from Golgi Elements.

In the undifferentiated cell, such as a spermatogonium or an oögonium, the Golgi apparatus consists of a number of rods stuck upon the surface of the archoplasm or condensed protoplasmic substance surrounding the centrosome.

In *Limnæa* or *Helix* (*16*) the Golgi apparatus, during oögenesis, spreads out through the cytoplasm, its individual units increasing greatly in number (Pl. II, fig. 5). During this process it seems probable that the original archoplasm becomes divided out among the various Golgi elements or dictyosomes, so that finally each little group of two to four or five Golgi rodlets reposes on a part of the much-divided archoplasm. In *Limnæa* this archoplasmic substance can be traced back to the original archoplasm of the oögonium. In the subsequent cleavage of the egg there comes a time when the Golgi elements, hitherto scattered haphazardly in the cytoplasm of the blastomeres, finally take up their position near the nucleus, and in an excentric position. The archoplasm of each daughter blastomere is therefore regenerated from a part of the original archoplasm of the oögonium which gave rise to the egg (*16*).

But now when we turn to the oögenesis of *Patella* or an ascidian we discover a further complication. In *Patella* and the ascidians the Golgi apparatus is undoubtedly associated more or less directly with deutoplasmagenesis. From the observations we have made on the oögenesis of *Patella* it seems certain that the Golgi elements are directly stuck upon the surface of spheres whose chemical reactions are those of true yolk.

We then enquire as to the fate of the archoplasm in these cases. Do the yolk spheres represent the archoplasm loaded with food substances, or has the original archoplasm degenerated or

parted company with the Golgi rodlets or dictyosomes? We are inclined to believe that the original archoplasm may have become loaded with lipins and fats and thus metamorphose into yolk elements.

Basophility and Oxyphility of the Ground Cytoplasm during Oögenesis.

Pari passū with the evolution of the mitochondria and Golgi apparatus of the growing oöcyte, there may occur changes in the chromophility of the egg cytoplasm; probably there is some definite relationship between the ground cytoplasm and of the degree of spreading out and development of the protoplasmic inclusions. More possibly, however, the relation is between the nucleus itself and the surrounding cytoplasm. Hirschler has noted important changes in the chromophility of the egg cytoplasm during the growth of the ascidian oöcyte. In different growth stages the ground plasma shows a very variable staining, from which it may be concluded that during growth of the ovum it undergoes far-reaching metabolic changes.

Hirschler distinguishes three chief conditions of staining:—(1) primary oxyphilia, (2) basophilia, and (3) secondary oxyphilia. He believes that the Golgi apparatus may in some way be concerned with the passage of the chromophility of the cytoplasm from oxyphile to basophile, and considers that the nucleus is not directly concerned with the process.

The exact significance of changes in chromophility of the egg cytoplasm are unknown to us, but may indicate something of the growth metabolism of proteid substances.

Yolk Nuclei.

Wilson (*44*) says, "During the growth period (of an egg) a peculiar body known as the yolk nucleus appears in the cytoplasm of many ova, and this is probably concerned in some manner with the growth of the cytoplasm and the formation of the yolk. Both its origin and its physiological rôle are, however, still involved in doubt."

Many authors have loosely used the word "yolk nucleus" to mean any largish granule which they have noticed in the egg cytoplasm. The archoplasm and mitochondria have both been erroneously identified as "yolk nuclei." That there may be such a body as a true yolk nucleus, distinct from any other known cytoplasmic inclusion, cannot be doubted.

Hirschler (*22*) finds a true yolk nucleus which stains like the mitochondria during the early stages of its development. In the

youngest ascidian oöcytes Hirschler describes the presence of two granular bodies—one fuchsinophile, which is the chondriome (i.e. the representative of the mitochondria of the cell); the other stained black by osmium tetroxide, and forming the primordium of the Golgi apparatus of the egg. From the former, which Hirschler calls the chondriome, develop both yolk nucleus and definitive mitochondria. With regard to Hirschler's use of the term "chondriome," the word here means the entire content of mitochondrial substance in the cell, whether a single grain, or many grains collectively, and this meaning is the one in which most French observers have used the word.

Hirschler says, "One can suppose that the small red (fuchsinophile) yolk nuclei of the young oöcytes, even alone on account of their specific staining affinities, represent the chondriome of these cells, and that during the cell growth, out of this chondriome, which consists of small mitochondrial bodies, are produced on the one hand small granular mitochondria, and on the other hand the peculiar substance of the yolk nucleus. In this view, the yolk nuclei would be regarded as derivatives of the chondriome, and such an interpretation would then harmonize with the accounts given in the literature. But by simply looking at the facts alone, it seems that the mitochondria and the yolk nuclei have a common origin, and develop out of fuchsinophile spherical bodies, which represent at the same time mitochondria and the youngest stages of the yolk nuclei."

Following out the history of the yolk nucleus of ascidian eggs, Hirschler remarks, "As long as the yolk nuclei exhibit a red or reddish staining (fuchsin) they appear for the most part as compact spherules which are directly applied to the nuclear membrane. Later, however, the mitochondrial substance is given off from them, and they change their form and structure quite considerably in older oöcytes."

A kind of capsule becomes formed around the periphery of the growing yolk nucleus, while the interior of the latter gradually comes to stain in the same way as the ground cytoplasm. Hirschler continues, "But before the yolk nuclei have received their capsular form, quite peculiar stalks develop out of their substance, by which they are attached to the nuclear membrane. Usually a yolk nucleus possesses only one stalk, but some have two or even three." These stalks are intimately related to the nuclear membrane and thence to the chromatinic reticulum. Hirschler says with reference to the latter fact, "One could suppose that through these stalks certain nuclear substances are led in a fluid state through the nuclear membrane into the yolk nucleus and promote the growth of the latter." In support of this view Hirschler states that he finds granules, possibly chromatin, lying in the substance of the yolk nucleus.

Later the yolk nucleus (or nuclei) disappear without leaving a trace. (See also page 139.)

Sufficient work has not been carried out in the light of the newer interpretations of the inclusions of the cytoplasm to enable us to take a satisfactory survey of the conditions leading to the formation of the "yolk nuclei" in forms such as the arthropod or the vertebrate. In mammals the archoplasm has long been known as the "yolk body of Balbiani," but probably in no mammal does the archoplasm form true yolk. The "yolk nucleus" of the spider egg or the ascidian appears to be different from the archoplasm.

Graphic Representation of the Formation of the "Yolk" in Various Forms.

In the following section we have attempted to represent graphically the manner of formation of the yolk and associated bodies in several forms. We recognize several grades of progressive complexity. At one end we find such a case as *Grantia,* where the yolk is formed as vacuoles in the ground cytoplasm, and where neither mitochondria nor Golgi apparatus take direct part in the production of yolk; at the other end we find such an example as the ascidian, where the formation of the "yolk" is extraordinarily complex. Intermediate forms are found in *Patella,* and possibly *Rana.* Such a mammal as *Lepus* is specialized and simplified: the mitochondria may contribute to the formation of fat, while the Golgi apparatus does not appear to be altered.

These graphic representations are based on observations which in some cases are at present difficult to prove or disprove, and to which future work may lend a different interpretation. In each case we begin in the oögonium with Golgi elements and mitochondria, and by the time the oöcyte has become full grown the latter bodies may metamorphose in a most complicated manner, or they may simply have grown in bulk or in the number of their individual parts, without having become loaded with food substances which would cause them to be classified as "yolk."

PORIFERA.

Grantia compressa.

Oögonium.		*Full-grown Oöcyte.*
Mitochondria	→	Mitochondria.
(Ground cytoplasm)	→	Yolk spheres.
Golgi apparatus	→	Golgi apparatus.

MOLLUSCA.

Helix, Limnæa, etc.

Oögonium. — *Full-grown Oöcyte.*

$$\begin{tikzcd}
\text{Mitochondria} \arrow[rr] \arrow[drr, "?"] & & \text{Mitochondria.} \\
& & \text{Yolk spheres.} \\
\text{Golgi apparatus} \arrow[rr] \arrow[urr] & & \text{Golgi apparatus.}
\end{tikzcd}$$

Patella vulgaris.

$$\begin{tikzcd}
\text{Mitochondria} \arrow[rr] \arrow[drr] & & \text{Mitochondria.} \\
& & \text{Yolk spheres associated with Golgi elements.} \\
\text{Golgi elements and archoplasm} \arrow[urr] \arrow[rr] & & \text{Definitive Golgi apparatus with unchanged archoplasm.}
\end{tikzcd}$$

ASCIDIA.

$$\begin{tikzcd}
\text{Mitochondrium (chondriome)} \arrow[rr] \arrow[drr] \arrow[ddr] & & \text{Definitive mitochondria.} \\
& & \text{Yolk spheres.} \\
& \text{Yolk nucleus (soon disappears)} & \\
\text{Golgi apparatus} \arrow[rr] \arrow[uurr] \arrow[drr] & & \text{Definitive Golgi apparatus.} \\
& & \text{Golgi apparatus associated with yolk spheres.}
\end{tikzcd}$$

MAMMALIA (like *Lepus*).

$$\begin{tikzcd}
\text{Mitochondria} \arrow[r] \arrow[dr] & \text{Definitive mitochondria.} \\
& \text{Fat.} \\
\text{Golgi apparatus} \arrow[r] & \text{Definitive Golgi apparatus.} \\
\text{Ground cytoplasm (?)} \arrow[r] \arrow[dr] & \text{Scanty yolk.} \\
& \text{Fat}
\end{tikzcd}$$

INSECTA (*Apanteles*).

$$\begin{tikzcd}
\text{Mitochondria} \arrow[r] \arrow[dr] & \text{Definitive mitochondria.} \\
& \text{Yolk.} \\
\text{Golgi apparatus} \arrow[r] & \text{Golgi apparatus.} \\
\text{Nucleus (nucleolus)} \arrow[r] & \text{Secondary nuclei.}
\end{tikzcd}$$

Then possibly the nucleoli may produce "yolk" (*Periplaneta*; page 140) in certain insects.

AMPHIBIA (*Rana*).

Oögonium.		*Full-grown Oöcyte.*
Mitochondria	→	Definitive mitochondria.
	→	Yolk bodies.
Golgi apparatus	? →	Golgi apparatus yolk (i.e. apparatus elements slightly enlarged).

On the Fate of the Mitochondrial and the Golgi Apparatus Yolk Body during Embryogeny.

The mitochondria can metamorphose into fat spheres or yolk bodies during oögenesis. This probably means that the protoplasmic substratum which forms the basis of the mitochondrium, or which in the case of the Golgi apparatus is possibly the archoplasm, becomes loaded with fatty substance, phosphorized or otherwise. This metamorphosis leads to the granules in question becoming inert, and chromophobe with most dyes.

Now, during organogeny the yolk bodies are drawn upon to provide the energy for development, and they become smaller and smaller. A question is whether the yolk granule formed from the mitochondrium, or from a part of the Golgi element, changes back to its former state, or again metamorphoses into a protoplasmic granule? This is a point to the elucidation of which future work on the minute cytology of the embryonic tissues alone can give an answer.

Chromidia in Metazoan Oögenesis.

The word "chromidium" is used by protozoologists to mean a small, generally "solid" body, composed of true chromatin and lying in the cytoplasm of the cell. In *Arcella*, for instance, the presence of true chromatinic chromidia at certain stages in the life cycle of this protist cannot be doubted. As Dobell has noted in his paper (*6*), workers on metazoan cytology, of whom Popoff is an example, have erroneously identified various structures as true chromidia; Popoff identifies what we now know to be the Golgi apparatus of the Mollusc spermatocyte as the chromidia (*34*).

Many workers on oögenesis have wrongly identified the egg mitochondria as chromidia;* this misinterpretation has been due

* Can chromidia metamorphose into mitochondria? Does the plasmosome of the nucleus arise from chromatin, and can nucleolar substance give rise to mitochondria? These questions are all more or less intimately related, and still unanswered.

to the fact that few cytologists take the trouble to examine carefully the fixing and staining properties of those bodies which they call "chromidia." Jorgensen (*26*), in a paper on the oögenesis of *Grantia compressa,* calls the mitochondria "chromidia." Dendy (*5*) has followed Jorgensen, and by both authors the sperm middle piece is called a "chromidium," though it should be noted that these observers were not aware that the body they described was the spermatozoon (see paper (*19*)).

Nearly all cytologists use some form of iron alum hæmatoxylin for staining. While we disagree with the statement that such hæmatoxylin stains cannot be relied upon, it is true that these methods tinge a black or grey-blue colour many different cell bodies. To fix a tissue in ordinary Flemming and to stain in iron hæmatoxylin, and then to describe in such preparations any blackly stained granule as chromatin or a "chromidium," is unjustifiable; to describe any cell substances which stain basiphil in the so-called chromatin or nuclear dyes as chromatin is equally unjustifiable, yet perusal of cytological work carried out by many zoologists will show that it is customary to regard basophil materials as chromatin. One example which reminds us of the care which must be taken in the interpretation of cytological staining methods will suffice: methyl green, a dye which is extremely useful for staining chromatin, will also stain mucin of goblet cells, and the matrix of cartilage; it is sometimes found that after chrome-osmium fixation pyronin and methyl green may stain oxyphil materials green, and basophil ones red.

It should be noted here that we have no certain methods for differentiating cell chromatin, but there are numbers of ways which enable us to detect and separate out substances which are not chromatin.

Let us take the case of the so-called sponge-egg "chromidia." After chrome fixation and iron hæmatoxylin or iron brazilin staining, these bodies stain black or brownish respectively; Jörgensen therefore calls them "chromidia." Going somewhat further into the matter, we find that by fixing in chrome osmium and staining in Ehrlich's hæmatoxylin, the nuclear chromatin goes blue, while the so-called "chromidia" either do not show, or are faintly brownish and not stained; fixing the sponge in Carnoy's fluid and staining by any other methods fails to reveal the "chromidia"; fixing and staining by Champy-Kull (*18*), the "chromidia" go red (fuchsin) and the chromatin of the nucleus blue (toluidin blue), while the nucleolus (plasmosome) goes red. Therefore we can pronounce the "chromidia" not to be chromatin, because they are dissolved away by Carnoy, because they fail to stain like chromatin in Ehrlich's hæmatoxylin or by Champy-Kull's method, and because their histo-chemical reactions are those of mitochondria which have no direct relation to chromatin.

In the animal egg, besides the mitochondria which have thus been mistaken for chromidia, we have the Golgi apparatus. Since the latter is never demonstrated in eggs, by the usual methods, we do not believe that Golgi grains have so far been misinterpreted as "chromidia." The case of the male cells has already been mentioned.

It may be noted here that true chromidia, by which we simply mean granules of chromatinic nature distinct from the nucleus, but traceable to nuclear activity, do occasionally occur in metazoan oögenesis. The cases of insect oögenesis are well known (*2*, *17*); in Hymenopterous insects especially are often found granular chromatinic structures free in the cytoplasm, and quite distinct from either mitochondria or Golgi apparatus. Such cases have been noticed, but less well studied in other Invertebrata. It can be stated that true chromidia (chromatinic) are not characteristic of metazoan cells. Nearly every so-called case of the occurrence of chromidia in Metazoa is really a misinterpretation of the mitochondria.

On page 153 we have given a scheme showing the fixing and staining reactions of chromatinic structures, plasmosome, and of the cytoplasmic inclusions such as the mitochondria. It will be noted that it is possible to stain both mitochondria and true chromatinic structures in different colours in the same preparation. For the modus operandi of these methods, see (*11*) and (*18*).

The so-called Chromatin Emission during Oögenesis.

There still appears to be a rooted belief that the nucleus is able to, and constantly does, pass out granular emissions of true chromatin into the egg cytoplasm; it is also believed, but with more justification, that the nucleolus or plasmosome may pass out and break up into granules which are in some way concerned with yolk formation. Working with inappropriate methods, and in ignorance of recent researches on the cytoplasm, some observers are wont to describe any basophil or even chromophil cytoplasmic granules as chromidia, and to trace the origin of such granules to the nucleus.

Among more modern workers, Schaxel (*37*, *38*) has written a great deal on these questions; in the polychæte worm, *Aricia fœtida* (Claparède), for instance, he describes how, during oögenesis, the nuclear matter increases in bulk, and then, "When the chromatin increase has reached a certain stage, there appears, with simultaneous cell growth, a dense mass of numberless chromatin

particles on the whole outside of the nuclear membrane, soon becoming heaped at many places into larger clusters, so that they form striking, scaly masses in the immediate neighbourhood of the nucleus. This emission process persists for a fairly long time. Nucleus and cell body increase simultaneously in volume."

These quotations from Schaxel's work may be taken as typical. Two obvious objections may be raised against his interpretation: (1) Schaxel produces not one jot or tittle of evidence that the granular particles *are* chromatin; and (2) he has not shown satisfactorily that the granules come from the nucleus at all.

Now with regard to the first objection it will at first seem natural enough, from the point of view of the older technique, to regard such an extranuclear basophil mass as emitted chromatin, but modern work on the mitochondria of the female germ cell allows us to look at the facts from quite another point of view, for just such appearances as Schaxel figures are produced by the mitochondria at certain stages of oögenesis.

We further believe that certain at least of the appearances figured by Schaxel as chromophil granules flattened upon and adhering to the nuclear membrane, are artifacts produced by the inferior fixation methods employed. Even with non-acetic chrome osmium fixation bad preparations are occasionally produced in which a granular appearance of the nuclear membrane is to be seen. The mitochondria during their dispersal through the egg cytoplasm become very fine, and we have little doubt that fixatives of unsuitable osmotic pressure would cause those grains near the nuclear membrane to be driven into or upon the latter so as to produce the appearance found by Schaxel.

Schaxel, moreover, has not used the methods which best discriminate between chromatinic and non-chromatinic matter. He falls into the error of relying far too much on the original Flemming acetic mixture and iron alum hæmatoxylin method. Schaxel is not the possessor of a unique technique unknown and unattainable by other workers; he simply uses methods which are now known to be inadequate to reveal many important cytoplasmic constituents, and which can be employed by any zoologist.

Recent workers such as Hirschler, Weigl, Nussbaum-Hilarowitz and ourselves do not find true chromatin behaving in the manner Schaxel describes. It is true that in rare cases, such as in insect and some other eggs (*2, 17*), a definite formation of presumably true chromatin particles is found in the egg cytoplasm, and several observers trace these granules as originating from the nucleus (nucleolus), but similar cases are rare. These definite cytoplasmic chromatin granules are to be distinguished from such "emitted" granules (mitochondria) as have erroneously been described as chromatin by Schaxel.

	1	2	3	4	5	6
TECHNIQUE EMPLOYED.	Fixation in alcohol acetic. Carnoy (at least 1 hour); Petrunkewitsch or Gilson (over night), and staining in hæmatoxylin, of Ehrlich, or toluidin- or thionin and eosin.	Method of Champy-Kull, i.e. fixation in chrome-osmium, staining in acid fuchsin aurantia and toluidin-blue.	Altmann-Bensley. Chrome-osmium fixation, staining in acid fuchsin and methyl-green	Chrome - osmium fixation and staining in Ehrlich's hæmatoxylin or toluidin-blue and eosin.	Cajal's formol-uranium nitrate and silver method for Golgi apparatus counterstained in safranin (or in methyl-blue eosin or methyl-green).	Mann-Kopsch, i.e. fixation in corrosive-osmic, after-treatment in OsO_4 of 2 p.c. for 14 days. Then stain in a basic dye like safranin.
CHROMATIN (nucleus) AND CHROMIDIA.	Blue.	Blue to greenish.	Green.	Bluish.	Blue, red or green, according to colour of basic stain used.	Red in safranin, etc.
MITOCHONDRIA AND GOLGI APPARATUS.	Will not show, because they have been nearly or quite dissolved away, and morphologically altered by the fat solvents of the preparing media.	Mitochondria red, Golgi apparatus rarely shows, but when it does so it is red.	Mitochondria red, Golgi apparatus also as for 2.	Do not show, or faintly oxyphil. Granules as such not identifiable.	Mitochondria golden to dark brown, Golgi apparatus black.	Yellowish to black, will not stain in safranin.
NUCLEOLUS (Plasmosome).	Red.	Red.	Reddish.	Bluish.	Reddish or colour of plasma stain.	Reddish.

Under this section we are obliged to conclude that the so-called chromatin emission of Schaxel is very probably a misinterpreted stage in the evolution of the mitochondria, described from preparations made by methods which do not produce the best results.

Such definite cases of extrusion of chromatinic granules as are known (*17*) do not resemble anything described by Schaxel.

The Nucleolus and the Formation of Yolk.

The nucleolus (plasmosome) of the germinal vesicle of young oöcytes may also give rise to bodies which are themselves to be considered yolk granules, or which metamorphose into yolk. Hempelmann (*20*) and Buchner (*2a*), for instance, in the archiannelid *Saccocirrus*, describe the partial fragmentation of the young oöcyte nucleolus, the migration of these fragments through the nuclear membrane, and the subsequent formation of yolk from them.

The secondary nuclei of insect eggs, which may originate from the nucleolus do not seem to have any connexion with such bodies described in *Saccocirrus*.

Note also Schreiner's work mentioned on page 143, and Dendy's observations on *Grantia* (5). Schaxel's descriptions and figures do not coincide with Hempelmann's (*20*) observations for *Saccocirrus*, and the two processes are unalike.

The Mitochondria and Golgi Apparatus in Human Post-mortem Material.

The cells of the human body, like those of other animals, are known to contain the above-mentioned mitochondria and Golgi apparatus.

It has been found by experiment that very soon after death the protoplasmic inclusions partially or wholly disintegrate, undergoing a sort of plasmolysis; consequently post-mortem material, unless procured almost immediately after death, will not be suitable for a study of any of the cytoplasmic inclusions.

It should also be pointed out that the ether or chloroform used to produce anæsthesia may occasionally have an effect on the cell inclusions and so introduce artifacts, especially in small animals.

Mr. Carleton, of the Physiological Department of Oxford, informs us that he has been unable to note any changes in the Golgi apparatus of the gut cells of decerebrate cats, or in cats which have been continuously under an anæsthetic for an hour. It is nevertheless necessary to avoid tissues which have been exposed in any way to injurious agents.

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IV.—*Method for the Demonstration of the Golgi Apparatus in Nervous and other Tissues.*

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(*Read March* 17, 1920.)

One Plate.

The preparations I have the honour of showing to this Society have all been obtained by the following method:—

1. Fixation.

Small pieces of quite fresh tissues are fixed in—

Cobalt nitrate	1 grm.
Distilled water	100 c.c.
Formalin	15 c.c.

The solution can be prepared beforehand and keeps unaltered for months. Formalin need not be neutralized unless strongly acid or containing free sulphuric acid, in which case it is necessary to neutralize it by one of the usual methods, such as shaking with calcium carbonate and filtering before using. For the fixation of embryonic organs, and in all cases in which a shrinkage of delicate tissues is to be feared, the quantity of the formalin may be reduced to 10, 8, 6 c.c. for every 100 c.c. of distilled water. The pieces, about 3 mm. thick, are generally left six to eight hours in the fixing solution at room temperature. This time should be shortened to 3–4 hours, or even less in the case of certain tissues, such as cartilage, or of very small pieces, such as spinal ganglia of mice and rats, adrenals of mice, the pituitary body of the same animals, etc. Hollow organs, such as the stomach and intestine, are better fixed if partially filled with the fixing fluid and kept in it *in toto* for about one hour, after which time they are reduced to due proportions and treated according to their thickness. Pieces of spinal cord, cerebrum, cerebellum of adult animals give better results if fixed for about eight to ten hours. The fixation may be prolonged in special cases to 12–20 hours, but should not exceed twenty-four hours. For the difficult fixation of the testis of mammalia it is advisable to inject the fluid through the abdominal aorta and afterwards to plunge the entire organ in the fluid for some time before proceeding to cut off the necessary pieces. Small animals can be injected *in toto* from the heart,

allowing the blood to flow out from the wound made to expose it. If the injection is successful, organs and tissues become very quickly ready for the second stage of the method, and one must rapidly proceed to their extraction and reduction into small pieces, which are left in the fixing fluid for a short period, corresponding to about one-third or one-half of the time needed for the fixation of non-injected material. Should it be particularly interesting to have the outermost layers of certain organs well stained, these must be fixed with some of the surrounding tissue, such as fatty or connective tissue, the pia mater in the case of the central nervous system, etc. I have at present little experience of the fixation of material from low vertebrates and invertebrates. In general I should advise proceeding by tentative experiments, which are also necessary for the systematic study of the internal apparatus in some determined tissues, as the moment in which they become ready for the subsequent treatment appears to vary a little in almost every one of them. The fixation at a temperature varying between 25 and 37° C. has been attempted with some success, particularly in the case of cortex cerebelli of mammalia. It leads, however, to some special results which will be dealt with afterwards.

2. Impregnation.

The pieces are quickly washed twice in distilled water, their surfaces made smooth if necessary, and then placed in a 1·5 p.c. solution of $AgNO_3$. For very small fragments and structures which are easily impregnated, as the Fallopian tube of small mammals, 1 p.c. $AgNO_3$ can be used. For pieces of spinal cord of adult animals and organs containing much fat, the strength of the $AgNO_3$ solution may be raised to 2 p.c. The quantity of $AgNO_3$ solution changes according to the number of pieces; generally, no more than five or six are put in a specimen bottle of an approximate capacity of 30 c.c. They are left in the silver bath from twenty-four to forty-eight hours, according to their size. A longer stay, though often without danger, should be avoided as precipitates may form. As a rule the pieces, once in the $AgNO_3$ solution, are kept away from the light and at room temperature. In winter and if the temperature of the laboratory falls very much during the night, one may have recourse to an incubator at 25–28° C. The use of an incubator at 36–37° C. may be attempted with success for the spinal cord of adult mammals, and for pieces which are difficult to impregnate. This practice may be attended by good as well as by negative results, and ought to be arrived at by tentative experiments, in order to establish the most suitable length of time during which the pieces may be safely left in the incubator at certain temperatures.

3. Reduction.

The pieces are quickly washed twice in distilled water, and further recut so that their thickness does not exceed 2 mm. They are then transferred into Cajal's reducing fluid to be freshly prepared every time :—

Hydroquinone	1·5–2 grms.
Anhydrous sodium sulphite . . .	0·15–0·25 grms.
Distilled water	100 c.c.
Formalin	6 c.c.

First dissolve the hydroquinone in water and then the sodium sulphite before adding the formalin, to be neutralized only if strongly acid, as pointed out before. Instead of hydroquinone, pyrogallic acid may be used, though it appears to have a lesser power of penetration, and the pieces must consequently be smaller. Its use may be of some advantage if only a dark brown colour of the apparatus is desirable. Pieces are generally left in the reducing fluid from one day to the next. A longer stay, though harmless, is without purpose, as after about twelve hours the $AgNO_3$ appears to be completely reduced. Weaker solutions of hydroquinone are to be used only in special cases. Various attempts have been made to leave the pieces in the reducing fluid a few hours only, but either no special results have been obtained, or, in contradiction to Carleton's statement, the staining of the apparatus was insufficient in consequence of a probably incomplete reduction of the silver.

4. Embedding, Toning and Counterstaining.

The reduction having taken place, the method is ended, and the pieces may be washed in distilled water for a little while to extract the formalin, and cut by means of a freezing microtome. It is, however, preferable to pass them rapidly through alcohols of increasing strength, clear them by means of fluid cedar-wood oil, and embed them in paraffin melting at 48° C. They may also be embedded in celloidin, but rapidly, because absolute alcohol and ether have a tendency to dissolve the unstable reduced silver. Moreover, celloidin blocks must be cut as soon as possible, while paraffin blocks keep indefinitely, and may be cut, eventually in series, when most convenient. The sections, however obtained, free or stuck to slides, are mounted in Canada balsam or xylol-colophonium in the usual way. They show the apparatus stained black or dark brown on a more or less intense yellow or buff background. These preparations do not generally keep well, because the xylol of the balsam very often dissolves the reduced silver. Further, in most cases a counterstaining is desirable. For

these reasons it is preferable to transfer the sections, either single or stuck to slides by the albumin method, through xylol and alcohols of decreasing strength into distilled water, and tone them by means of a 0·1–0·2 p.c. acid solution of gold chloride, as suggested in my communication to the January Meeting of the Physiological Society, at which a preliminary note on the above described method was also communicated. The unstable reduced silver may be fixed by other methods, e.g. by the toning and bleaching process of Veratti, as published by Golgi, which has the advantage of imparting to the finished preparations a white, almost colourless background, though I find it rather more difficult of execution, and more expensive on account of the greater quantity of gold chloride solution required. The toned preparations can be either dehydrated and mounted or counterstained, as one may think desirable, the consecutive treatment being according to the stain chosen. For routine work I prefer alum-carmine, because it allows the handling of many sections or slides at the same time, does not usually require a successive differentiation, and imparts to both nuclei and cytoplasm a deep pink staining contrasting well with the black or dark grey colour of the apparatus. For the dehydration of sections stained with alum-carmine no absolute alcohol is required, as after the 95 p.c. alcohol clearing in carbol-xylol and mounting in balsam may follow.

5. General Considerations.

The present method is only a modification of the uranium nitrate method proposed by Cajal, who had already suggested the use of other nitrates, such as those of manganese and of lead. Various attempts were made by me with copper nitrate, but unsuccessfully. The same can be said of cobalt sulphate. Cobalt acetate I am still investigating, as it appears to be particularly suitable for the study of the internal apparatus in generative organs, and enables one to recognize in the middle piece of spermatozoa a very small structure, similar to a minute apparatus, to which I paid special attention after having seen some preparations of Dr. J. Bronté-Gatenby.

Cobalt nitrate, like uranium nitrate and arsenious acid, does not alter the Nissl's substance, as can be shown by counter-staining toned sections of spinal ganglia or spinal cord with neutral red, toluidin blue, crystal violet, etc. Much the same might be said of neurofibrils, on which subject, however, I propose to give a special demonstration in due course.

As pointed out in my preliminary communication, my method stains in certain conditions not only the internal apparatus, but also intracellular formations, which, according to their morphology

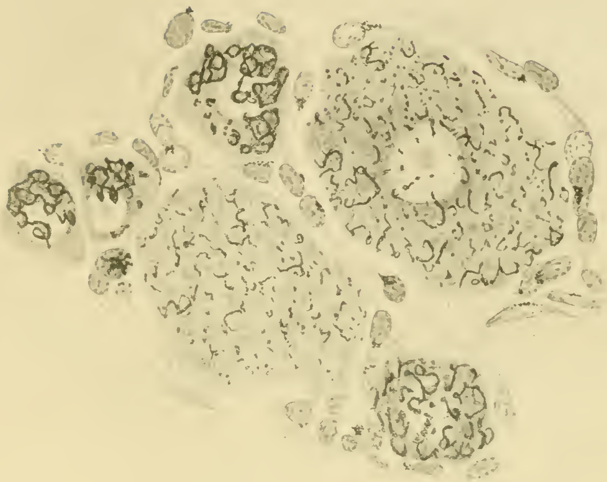
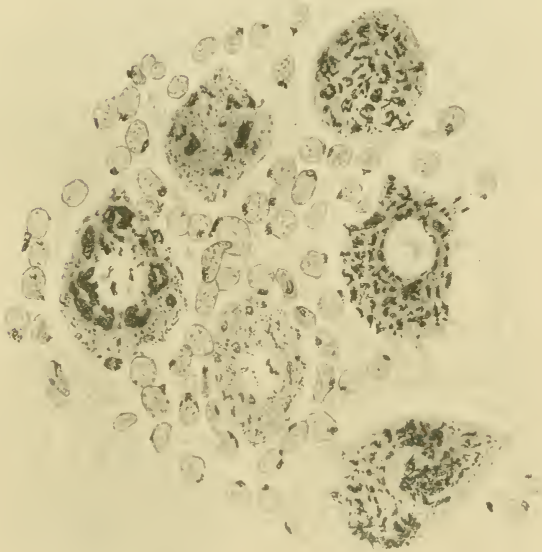


FIG. 1.—Golgi apparatus in spinal ganglion-cells of a young rabbit.
For comparison with fig. 2.



and arrangement, are to be considered as mitochondria. This was, in a way, to be expected, as in uranium nitrate preparations there also appear sometimes well-stained mitochondria; and Perroncito has shown that similar results can be obtained by Golgi's arsenious acid method, if the fixing solution is made to act for some hours at 45–50° C. The same happens almost constantly in the case of my cobalt nitrate modification if the fixation is prolonged to 18–24 hours at room temperature, or takes place with fluid previously warmed and kept at 36–37° C. for a few hours as explained above. An almost constant staining of both mitochondria and internal apparatus in the same preparations has been observed by me in transplantable sarcomata of rats and mice, and in the uterus glands and epithelium of some mammalia by the unmodified method described above, as can be seen in two of the preparations I am showing.

These various results, together with the extraordinary variations in the morphological aspect of Golgi's internal apparatus, strengthen the belief that we are not faced here by mere capricious precipitations of silver or by some artefact due to the methods of fixing and staining. In this respect it seems to me that my preparations from human Gasserian ganglion obtained five hours after death are particularly interesting (fig. 2). The apparatus, fixed when undergoing an evident process of autolysis, has lost much of its peculiar aspect and appears broken into irregularly shaped pieces, lumps and granules, which also occur, for instance, in parts of transplantable tumours undergoing a process of necrosis or in other degenerating tissues, but not in normal freshly fixed organs.

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V.—*On Acari from the Lungs of Macacus rhesus.*

By F. Martin Duncan, F.R.M.S., F.R.P.S., F.Z.S.

(*Read June* 18, 1919.)

One Plate and Two Text-Figures.

The first case of Acariasis in the lungs of the Common Rhesus Monkey (*Macacus rhesus*) to come under my observation was during September 1918, when I was assisting Dr. J. A. Arkwright in Trench Fever investigation at the Lister Institute of Preventive Medicine. Since then I have been able to investigate a number of cases from various other sources, and from these cases the material shown under the microscopes this evening, and the photographs, have been obtained.

The presence of these Acari is generally revealed by small, pale, whitish-yellow vesicles dotted about on the surface of the lung, and varying in size from $\frac{1}{16}$th to $\frac{4}{16}$th of an inch in diameter. On dissection these vesicles are found to communicate with small bronchi, and to have thin fibrous walls, which are generally lined internally with a layer of soft white or greyish-white débris, in the midst of which the mites rest. Although these cavities are commonly situated just beneath the pleura, they are also occasionally found in the depth of the lung. The Acari are always most numerous in the cavities just beneath the pleura, and from these "nurseries" they appear to wander into the small bronchi that open into the cavity, and thence make their way deep into the tissues of the lung, their presence in this situation having been demonstrated in several batches of serial sections of lungs.

On opening a vesicle the mites will generally be seen resting with their legs apparently more or less embedded in the débris lining the cavity. They begin to move about, however, very soon after the vesicle has been cut open, and if left alone may be seen to crawl about and enter the bronchi opening into the vesicle, and to disappear from view. The débris within the vesicle seems to consist chiefly of desquamated epithelial cells and leucocytes, with minute crystals, possibly of hæmoglobin. A few bacteria have also been detected in smears.

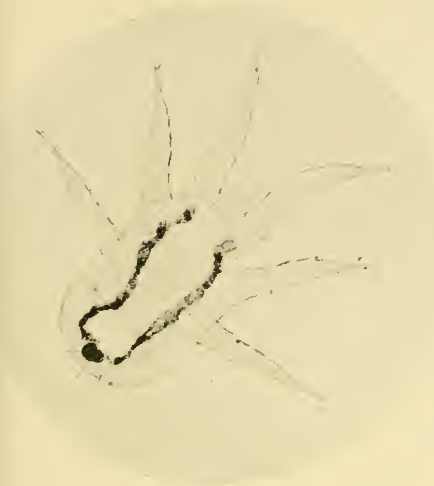
It is interesting to note that in all the cases so far examined the presence of these Acari in the lung does not appear to have caused serious illness or death—death in each case being due to some other clearly defined cause. At the same time the presence

of these Acari in large numbers must set up a certain amount of irritation likely to predispose to pulmonary disease, and may be a factor, if not the actual reason, for the marked susceptibility of Macacus Monkeys to such diseases. Infestation probably takes place early in life, as many of the monkeys examined were young individuals, perhaps half grown. How the Acari find entrance to the lung in the first instance has yet to be established, but probably infestation takes place via the nasal passages or mouth. Once established in the lung, however, breeding takes place, and apparently the whole life-cycle can be passed through in this environment, as I have found young and advanced larvæ, nymphs, and adults present in the lung. The number of Acari present in the vesicles varies, ranging from a single individual to twelve or fourteen. Males appear to be few in number as compared with females.

The Acari in the larval, nymph, and adult stages of their existence are semi-opaque, ashy-white in colour, the mid-intestine and diverticulæ showing through the semi-transparent surface of the dorsal skin in pale opaque, cream-coloured lines. The epidermis is soft and easily ruptured, therefore considerable care is necessary in handling and mounting these Acarids for microscopic examination.

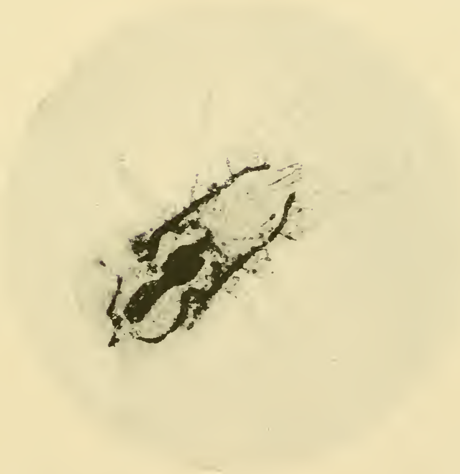
The larva is six-legged, short and oval in shape, averaging $\frac{1}{50}$th of an inch in length of body, $\frac{1}{100}$th of an inch across the thorax, and $\frac{1}{80}$th of an inch across the greatest width of abdomen. The first pair of legs average $\frac{1}{75}$th of an inch in length, and the second $\frac{1}{85}$th and third pair $\frac{1}{75}$th of an inch. The legs have a few stout hairs, and are cylindrical and tapering to the slender foot. The tarsus is very slender, with equal curved claws, and well-developed pulvillus, which extends between and beyond the claws. The palps are tapering, and appear more prominent and, in comparison, slightly longer than in the adult, each palp bearing a long stout terminal hair. The mandibles are pointed, and straight-edged on their inner surface, like the blade of a knife.

The nymph and adult closely resemble each other in size and shape, the most distinctive feature in the nymph being the absence of the external genital pore. The palpi are short, composed of three segments, and crowned with a minute apical hair. The body is oblong, broader at the abdominal extremity, narrower towards the thorax. Average length of body of adult female, $\frac{1}{25}$th of an inch; average width across thorax, $\frac{1}{85}$th of an inch; average across greatest width of abdomen, $\frac{1}{64}$th of an inch. The genital pore is situated centrally on the anterior part of the ventral surface of the abdomen, as a transverse oblong slit with a slightly thickened rim. The mandibles in the adult are chelate, have slender curved points, and rest within a transparent sheath. The legs are cylindrical and tapering, each segment bearing a few hairs.



Larva × 60.

Adult ♀ × 60.

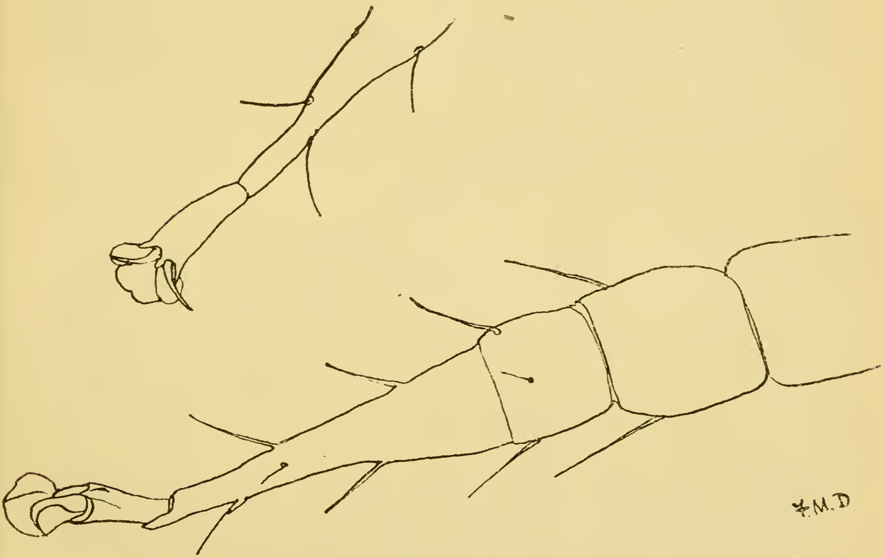


Adult ♂ × 60.

The claws of the tarsus are well developed and strongly curved, and the pulvillus extends between and considerably beyond them. Average length of first pair of legs, $\frac{1}{100}$th of an inch; of the second pair, $\frac{1}{150}$th of an inch; of the third pair, $\frac{1}{120}$th of an inch; of the fourth pair, $\frac{1}{100}$th of an inch. The stigmata are oval and open on the ventral surface of the thorax between the third and fourth legs.

A dorsal shield or scutum is present, but is somewhat difficult to detect in whole-mounted specimens.

From the material I have so far been able to examine I have

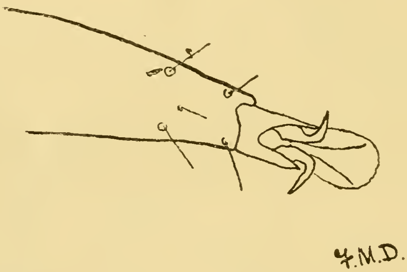


Tarsus of second leg of larva. × 500.

obtained only two specimens that are probably males. I have judged these to be males from their slightly smaller and more slender build, plus the absence of the vulvar orifice and the presence of a special anterior ventral orifice; also the small anal projection is within the margin and not, as in the nymph and female, upon it. What is probably the male genital orifice can be made out as a small circular aperture close behind the hypostome; and from it a tube can be traced, with some difficulty, leading posteriorily for a certain distance beneath the ventral cuticle. This tube is not easy to see in my specimens, and might from a casual examination be mistaken for a longitudinal furrow. The average length of body is $\frac{1}{40}$th of an inch; the width across middle of

thorax, $\frac{1}{100}$th of an inch; across greatest width of abdomen, $\frac{1}{80}$th. Length of first pair of legs, $\frac{1}{100}$th of an inch; second pair, $\frac{1}{120}$th; third, $\frac{1}{130}$th, and the fourth pair, $\frac{1}{110}$th of an inch. All the legs are cylindrical, tapering to the well-developed strongly curved claws, with the extending pulvillus, and are sparsely clothed with stout hairs. The palpi are short, three-jointed, and the mandibles chelate.

So far no eggs have been detected either in the vesicles or in bronchi containing the Mites. It is possible that these Acarids are larviparous, for Weidman (*6*)* mentions finding a young larva in the vicinty of a ruptured female. Professor Allman (*1*), describing a new genus and species of Tracheary Arachnidians, states that on rupturing the walls of the abdomen of female specimens, he frequently obtained young larvæ "formed as yet with only six legs, and the abdomen scarcely visible." Allman



Tarsus of third leg. Adult. × 500.

states that these small six-legged larvæ were also found in numbers along with the adults. These Mites were discovered by Allman in the posterior nares of a Seal (*Halichærus gryphus*), and named by him *Halarachne Halichæri*. His drawing of the larva bears a striking resemblance to the larvæ found in the lungs of *Macacus rhesus*.

Acari from the lungs of different species of Monkeys (including *Macacus rhesus*) have been described by Newstead and Todd (*3*), by Newstead (*4*), Landois and Hoepke (*5*), but the descriptions of these authors do not coincide with all the morphological details of the Mites I have had under examination. Weidman (*6*), however, has given a full and well-illustrated account of some Mites that he had obtained from the lungs of a single Rhesus Monkey, and his description coincides in all particulars with the specimens that I have obtained from all the lungs that have so far

* The italic figures within brackets refer to the Bibliography at end of the paper.

passed through my hands. For this Mite he proposes to establish the name *Pneumonyssus foxi.** Of the specimens described by the previously cited authors, the *Pneumonyssus griffithi* of Newstead most closely resembles the species under consideration; but it does not coincide in all details, nor do the rather sketchy outline drawings illustrating his paper.

Mites belonging to the *Cytoditinæ* are, according to Neumann (7), found in the subcutaneous or inter-muscular connective tissue surrounding the respiratory organs, or in the air-sacs of birds. The Cytodites inhabit the air-sacs of the Gallinacea, especially Fowls and Pheasants. They enter the bronchi, and even reach the air-canal in the bones. They often exist in large numbers in the air-sacs without betraying their presence during the life of their host, and apparently causing no serious inconvenience or ill-health, though occasionally they have been known to be so numerous as to crowd the bronchi, and cause by their irritation of the mucous membrane fits of coughing. The evidence, however, appears to be quite inadequate to permit acceptance of the statements of various German authors that these Mites are the frequent cause of enteritis, peritonitis, etc., in Fowls. *Symplectoptes cysticola* belonging to the second genus of Sarcoptid Cysticoles is also peculiar to the Gallinacea living in the connective tissue, but does not appear to affect the health of the birds. The cysts containing these Mites are yellow oval bodies about 1 mm. long, sometimes very numerous, and their contents are soft, granular, and adipose or calcareous—much like those of tubercle; and are to be found on the abdominal viscera, in the peritoneum, in the muscles, and beneath the skin. Biologically and pathologically, the account given by Neumann of these Acarids peculiar to the Gallinacea is of great interest as showing their relatively similar results in the host to those of the Acari infecting the lungs of Mammals.

I would express my thanks to Mr. Chas. D. Soar for looking over my notes and specimens.

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* After Dr. Herbert Fox, who Weidman states performed the autopsy on the Monkey, recognized the parasitic nature of the lesions and submitted all the material to him.

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VI.—*The Lycopodium Method of Quantitative Microscopy.*

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(*Read March* 17, 1920).

One Text-Figure.

The use of the microscope for quantitative measurements is attended by many difficulties. Such determinations are, however, of great importance, since they offer the only available method of solving certain analytical problems. For example, the proportion of maize starch added to the ordinary wheat flour cannot be determined by chemical methods, which will give accurately the total starch present, but fail to differentiate between different starches. Similarly one can determine chemically the total woody structures (crude fibre) in a powder-like pepper or gentian root, but cannot tell what proportion consists of foreign stone cells, if such are present. Both these problems can be satisfactorily solved by microscopical methods.

In carrying out work of this kind attention must be given to such thorough mixing of the materials as will assure efficient sampling. The necessity for care in this particular is evident from the fact that the result is based upon observations made of the composition of a very minute quantity of powder—namely, that which occupies about twenty fields of view. Assuming that there is about 0·2 grm. of substance in 10 to 20 c.c. of the fluid used as a suspending agent, and that one is working with a one-sixth inch objective, then under ordinary circumstances twenty fields will represent from one-250th to one-100th part of a milligramme of powder. The mixing then must be so thorough that every 200th part or thereabouts of a milligramme of the mixture shall have a composition similar to that of the whole sample.

The suspending agent, too, must be of a suitable character. It should not bring about a separation of the constituents, and should not allow the suspended material either to sink or to rise too rapidly. It should also contain no structures that could be mistaken for any that are present in the powder under investigation.

Further, the materials for the determination of which quantitative methods are needed are of very varied types, ranging from substances like starches, whose structure is quite simple, to powders of increasing complexity, such as olive stones, mixed flours, pepper, insect flowers, etc.

Perhaps the greatest difficulty with which one is faced is to devise a simple means of ascertaining the quantity of material in which certain specified particles have been counted by the microscope.

Some of the earlier methods proposed and used (*1* to *5**) give only approximate results, with an uncertain range of error, and may lead to erroneous conclusions. Other more reliable methods require either a specially constructed mechanical stage (*6* and *7*), or a specially made glass slide with squares of a known size ruled over a limited area equal to that of the cover-glass used (*8*), or a glass slide with a well of a particular depth and squares engraved upon the enclosed area (*9*). All these methods are of limited application, and are tedious to carry out.

To bring quantitative measurements within the sphere of regular microscopical practice, one needs a general method applicable with slight modifications to a wide range of substances, and requiring no specially constructed apparatus. The method should be simple in principle, and reliable within comparatively narrow limits for all percentages of admixture. The use of lycopodium as suggested by the author (*12*) provides such a generally applicable process which gives results rarely showing an error greater than 10 p.c. of the amount to be determined. It is therefore possible, for example, in dealing with an admixture present to the extent of 20 p.c. to obtain a result that will lie between 18 and 22 p.c. Results showing this order of accuracy are quite equal to many of those obtained by chemical operations, and the careful use of this lycopodium method entitles microscopical quantitative determinations of suitable materials to rank on an equality with those made by the use of many well-tried chemical processes.

Outline of the Method.

In general outline the method of procedure is as follows:— The nature of the admixture is first ascertained, and a powder containing this ingredient and the pure substance in equal proportions is prepared. Of this 50 p.c. mixture a convenient weighed amount (about 0·2 grm. in most cases) is mixed with a weighed quantity (about 0·1 grm.) of lycopodium spores, and with a suitable volume (about 20 c.c.) of a suspending agent such as mucilage of tragacanth, olive oil or castor oil.

A drop of the suspension is mounted for microscopical examination and the number of lycopodium spores and of characteristic elements of the powder are counted in ten fields selected according to the scheme described below. A second drop of the suspension is mounted and ten fields counted as for the first slide, and the

* The italic figures in brackets refer to the Bibliography at the end of the paper.

result should agree closely with that previously obtained. In case of a disagreement greater than 10 p.c., which will rarely occur in practice, fresh counts must be made.

One next prepares a suspension of a similar weighed quantity of the article to be examined, mixed with an amount of lycopodium spores equal to the weight of spores used in the first part of the experiment. Drops of this suspension are mounted, and counts of twenty fields are made as in the former case.

For both suspensions the number of characteristic particles counted for 100 lycopodium spores is calculated. These two numbers represent the quantities by weight of one ingredient present in equal weights of the two mixtures, and since one percentage is known, the other is immediately obtained by simple proportion.

Example.

An example will simplify the explanation. It was desired to find the proportion of maize starch that had been added to some ordinary wheat flour. A mixture of wheat flour and maize starch in equal proportions was prepared, and 0·2 grm. of this mixture was carefully mixed with 0·1 grm. of lycopodium spores, and about 20 c.c. of mucilage of tragacanth. A drop of the suspension was mounted, and the following counts obtained in ten selected fields:—

Lycopodium spores . .	14, 15, 7, 11, 11, 5, 4, 13, 12, 10	= 102
Maize starch grains . .	43, 74, 53, 33, 61, 39, 25, 38, 57, 59	= 482

Giving 473 maize starch grains for 100 lycopodium spores.

A second slide was prepared by mounting another drop of the same suspension, and the counts obtained were as follows:—

Lycopodium spores . .	11, 11, 11, 7, 12, 7, 4, 9, 9, 12	= 92
Maize starch grains . .	51, 45, 57, 52, 63, 28, 23, 37, 47, 36	= 439

Giving 477 maize starch grains for 100 lycopodium spores.

It will be seen that the two sets of counts give closely similar results, and the average for the 50 p.c. mixture is 475 maize starch grains for 100 lycopodium spores.

The adulterated wheat flour was next similarly examined by mixing 0·2 grm. of the flour with 0·1 grm. of lycopodium spores, and about 20 c.c. of mucilage of tragacanth.

Ten fields from the first slide gave the following counts:—

Lycopodium spores . .	13, 10, 14, 20, 21, 11, 4, 14, 16, 12	= 135
Maize starch grains . .	48, 38, 42, 87, 64, 25, 24, 43, 77, 49	= 497

Giving 368 maize starch grains for 100 lycopodium spores.

Ten fields from the second slide gave counts as follows:—

Lycopodium spores . .	11, 6, 5, 8, 12, 5, 8, 8, 14, 6	=	83
Maize starch grains . .	30, 28, 34, 46, 26, 17, 18, 11, 44, 40	=	294

Giving 354 maize starch grains for 100 lycopodium spores.

The average for the twenty fields is 361 maize starch grains for 100 lycopodium spores.

Hence a certain weight of the 50 p.c. mixture contains 475 maize starch grains, and an equal weight of the adulterated flour contains 361 maize starch grains. Therefore the amount of maize starch in the flour is $50 \times 361 \div 475 = 38$ p.c. The actual amount of maize starch present in the flour was 37·8 p.c.

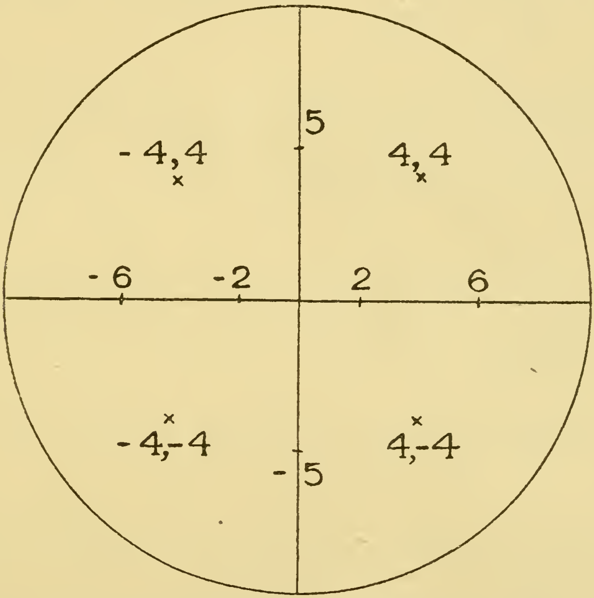
Remarks.

The flour and lycopodium are mixed by rubbing them together by means of a flexible steel spatula upon a glass plate or porcelain slab. The mucilage of tragacanth, which is prepared by mixing 1·25 grm. of powdered gum tragacanth with 2·5 c.c. of alcohol (90 p.c.), and adding 100 c.c. of distilled water as rapidly as possible and shaking vigorously, should be made some hours before it is needed for use so that the gum may be fully swollen. This suspending agent is best added a little at a time and thoroughly incorporated with the powder on the glass plate by trituration with the spatula. The mixture is transferred to a corked or stoppered tube, and the plate is cleaned by adding more mucilage in small quantities at a time, mixing it with any residue and transferring the successive quantities to the tube until none of the powder remains on the plate. The contents of the tube are thoroughly shaken up and a drop is quickly removed with a glass rod and mounted for examination.

The fields in which the counts are made are selected so as to include some from all parts of the preparation. This is necessary because the mount may be thinner on one side than on another, thus resulting in a slight unevenness of distribution. It is also necessary to avoid counting the same field twice, hence the positions of the fields are fixed beforehand by choosing such as are at certain measured distances from the centre of the cover-glass. The slide is placed on the stage of the microscope so that the centre of the cover-glass is immediately beneath the front lens of the objective, and the position of the right-hand near corner is read off on the two graduated scales of the mechanical stage. The slide is then moved by means of the milled heads which actuate the mechanical stage until each specified field is brought in succession under the microscope objective. The positions suggested for the fields are

those shown in the diagram, where the numbers indicate distances in millimetres from the centre of the cover-glass, while the + and − signs denote directions right and left or above and below the two diameters which are parallel to the directions of movement of the stage. To facilitate the actual counting, a disc of glass ruled in millimetre squares is dropped on to the diaphragm of the eye-piece and particles are counted successively along each line of squares until the whole field has been covered.

Mucilage of tragacanth and olive oil are the most generally



NOTE.—The figures in this diagram not preceded by a sign are to be read as having a + sign prefixed to them.

useful suspending agents. When the mucilage is used for oily powders, the oil or fat must be removed by a preliminary extraction with a suitable solvent. Olive oil may be used for the suspension of almost any material that is in an ordinary air-dry condition; it is particularly suitable for oily substances and in cases where it is necessary to use the polariscope, as for the analysis of a mixture of wheat and potato starches.

Measurements of Weight.

The use of lycopodium in the manner suggested gives one a measure of the relative proportions of the quantities of material

present in various preparations, so that when one is known the other can be calculated. It does not, however, enable one to determine the actual weights of the material in which the counts have been made. One can immediately ascertain the weight of any counted number of lycopodium spores if one knows the average weight of one spore, or, as it is more conveniently expressed, the number of spores per milligramme of lycopodium. Then, since the lycopodium and other material have been mixed in known proportions by weight, the corresponding weight of the other substance can be found by a simple calculation. This weight of material contains the counted number of characteristic particles, and from this can be calculated the number of such particles per milligramme. Hence for each substance there is a definite number representing the countable particles per milligramme, and these figures can be used as a means of characterizing or of standardizing the material. Such figures are not always suitable for calculating the amount of the substance present in mixtures, for which purpose it is better to obtain a special number by counting a mixture of known composition containing the same ingredients, but not necessarily in the same proportions as the material to be examined. The figures representing pure substances form a useful check upon those obtained by counting standard mixtures, but cannot safely be used in their place.

Determination of the Number of Spores per Milligramme of Lycopodium.

The number of spores per milligramme of lycopodium has been shown to average 94,000, a figure which was obtained by weighing accurately about 0·1 grm. of lycopodium and mixing it with a definite weight, about 10 to 12 grm., of olive oil or mucilage of tragacanth. A clean microscopic slide and cover-glass were then weighed, and a drop of the suspension was mounted on the slide, which was again weighed, thus giving the weight of the suspension on the slide. Twenty fields were then counted according to a pre-arranged plan similar to that advocated for quantitative microscopy in general. The total counted number of spores multiplied by the area of the cover-glass and divided by the area of twenty fields gives the number of spores under the cover-glass. From this number, the total weight of suspension and the weight of suspension mounted on the slide, one obtains the number of spores per milligramme.

The following example will show how the result is obtained:—

Weight of lycopodium	= 0·1102 grm.
Weight of suspension (oil and lycopodium) .	= 9·8560 ,,
Weight of suspension on the slide . . .	= 0·0276 ,,

The counts of spores in twenty fields were, 22, 25, 19, 18, 32, 4, 13, 10, 20, 25, 24, 26, 9, 18, 7, 10, 10, 22, 29, 30, giving a total of 373 spores.

Area of 20 fields	$= 20 \times 0{\cdot}2003$ sq. mm.
	$= 4{\cdot}006$ sq. mm.
Area of the cover-glass . . .	$= 322$ sq. mm.
Number of spores under the cover-glass	$= \dfrac{373 \times 322}{4{\cdot}006}$
	$= 29{,}983$
Number of spores per milligramme .	$= \dfrac{29{,}983 \times 9{\cdot}856}{0{\cdot}0276 \times 110{\cdot}2}$
	$= 97{,}170$

The mean of twenty-six determinations was 93,000. This figure was confirmed by calculation from the linear dimensions and the specific gravity of lycopodium spores, which gave the number 95,000. The mean of the results is therefore 94,000 (*13*).

Determination of the Number of Starch Grains per Milligramme of Maize Starch.

The number of starch grains per milligramme of starch dry at 100° C. can be used to characterize a starch. The figure was found by the following method in the case of a sample of commercial maize starch:—0·2 grm. of lycopodium was mixed with 0·1 grm. of maize starch and about 20 c.c. of olive oil. Four slides were prepared by mounting drops of the suspension, and the counts obtained gave 480, 477, 436, and 410 starch grains respectively, or on an average 450 grains for every 100 lycopodium spores. Hence there are $450 \times 94{,}000 \div 100$ starch grains for every milligramme of lycopodium, and since this weight of lycopodium was mixed with 0·5 milligramme of starch there are $2 \times 450 \times 94{,}000 \div 100 = 846{,}000$ starch grains per milligramme of air-dry starch. Allowing for 13·4 p.c. of moisture, there are $846{,}000 \times 100 \div 86{\cdot}6 = 977{,}000$ grains per milligramme of maize starch dry at 100° C. This number represents the sample of maize starch examined, but further research is needed before one can regard it as characteristic of maize starch in general.

Other Practical Applications.

Examples of the use of these figures as a means of standardization are to be found in the determination of the number of pollen grains present in such powders as Kousso and Insect Flowers. Kousso is a well-known anthelmintic, and consists of the dried

panicles of pistillate flowers of *Brayera anthelmintica* Kunth (N.O. Rosaceæ). This drug is frequently adulterated by the admixture of staminate flowers. The pistillate flowers always yield a few pollen grains which have lodged among the floral whorls or are adherent to the stigmas, but beyond this very small number pollen grains should be absent. It has been shown by Arthur Meyer (*7*) that this number should not exeeed 200 per milligramme, and if more than this number are found the presence of staminate flowers in excessive amount is definitely established.

In the case of Insect Flowers, one desires to find a powder having as high a number as possible of the characteristic pollen grains. Insect powder consists of the powdered unexpanded flower-heads of *Chrysanthemum cinerariæfolium* Vis (N.O. Compositæ), and if admixed with fully expanded flower-heads an inferior article results. The more fully expanded heads contain less pollen grains, and, if present in the powder, considerably lower the number of pollen grains per milligramme. Lehmann and Trottner (*14*) have shown that a powder made from the buds of Dalmatian Insect Flowers contains about 2000 pollen grains per milligramme, while partly expanded flowers yield 1000 to 2000 pollen grains per milligramme, and they suggest that any powder containing less than 500 per milligramme should be rejected as of inferior quality. The following example shows how this number was determined in the case of a sample of insect powder recently submitted to the author for examination as to its quality :—

Number of Pollen Grains per Milligramme of Insect Powder.

One grm. of the insect powder was carefully mixed with 0·05 grm. of lycopodium, and from the mixture a crude fibre was prepared by boiling it in a porcelain dish for thirty seconds with 50 c.c. of 10 p.c. nitric acid, and filtering under reduced pressure through a piece of moistened Horrockses' longcloth M. 2, stretched over a Buchner funnel supported in a filtering flask. The residue on the cloth was washed with about 100 c.c. of boiling water, returned to the dish and boiled for thirty seconds with 50 c.c. of 2·5 p.c. aqueous caustic soda, filtered through the cloth at the pump and washed with boiling water. The crude fibre containing the lycopodium was removed from the strainer and carefully mixed with mucilage of tragacanth until the volume was about 20 c.c.; the whole was well shaken in a stoppered tube and a drop was mounted for microscopical examination. The number of pollen grains was counted in a strip across a diameter of the cover-glass having a width equal to the diameter of the field of view in the microscope. This number was found to be 71. The number of

lycopodium spores present in 20 fields evenly distributed along the same diameter was 100, giving an average of 5 spores per field of view; hence in the whole diameter (equal to 45·8 fields of view) there were $5 \times 45{\cdot}8 = 229$ spores. There were therefore 71 pollen grains for every 229 lycopodium spores, and hence $71 \times 94{,}000 \div 229 = 29{,}100$ pollen grains for every milligramme of lycopodium (= 94,000 spores). Hence for 0·05 milligramme of lycopodium there were $29{,}100 \div 20 = 1450$ pollen grains, and since 0·05 milligramme of lycopodium was mixed with every milligramme of insect flowers there were 1450 pollen grains per milligramme of insect powder, which was therefore a perfectly satisfactory example from this point of view.

Conclusion.

Other more difficult problems upon which a certain amount of preliminary research has already been done are such as the determination of the percentage of wheat flour in mixtures of wheat and barley, and of the percentage of foreign stone cells in powders like pepper and gentian. Almost every problem presents its own special difficulties which may involve an inquiry into the range of variation found in different varieties of the same material, and a much more close scrutiny of details than has been necessary where only qualitative results were desired. For this reason progress must be slow, but the fundamental principle of the lycopodium method is applicable in all cases, and an ultimate solution of the difficulties is brought within the reach of microscopists.

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SUMMARY OF CURRENT RESEARCHES

RELATING TO

ZOOLOGY AND BOTANY

(PRINCIPALLY INVERTEBRATA AND CRYPTOGAMIA),

MICROSCOPY, Etc.*

ZOOLOGY.

VERTEBRATA.

a. Embryology, Evolution, Heredity, Reproduction, and Allied Subjects.

Individuality of Germ-nuclei in Cleavage Stages of Cryptobranchus allegheniensis.—Bertram G. Smith (*Proc. Amer. Soc. Zool.* in *Anat. Record*, 1920, **17**, 323). The germ-nuclei do not fuse in fertilization. In the first cleavage mitosis each gives rise to a separate group of chromosomes whose descendants pass separately to the daughter-nuclei. During the ensuing resting stage each germ-nucleus is represented by a structurally distinct vesicle. Throughout early cleavage the nuclear divisions are duplex, and the resting nuclei distinctly double. The genetic continuity of each half of the double nucleus has been clearly traced to an advanced cleavage stage, and even in the early gastrula. But the double structure becomes increasingly disguised.

J. A. T.

Causal Factor in Hatching of Chick.—A. G. Pohlman (*Anat. Record*, 1919, **17**, 89–104, 2 charts). Doubt is cast on Keibel's account of the importance of the musculus complexus in causing the bill and egg-tooth to strike forcibly against the shell. The musculus complexus does attain a maximum development before and at the stage of hatching, and shows a progressive atrophy after the chick is hatched, to the eighth day at least. But before the time of hatching the muscle is infiltrated with lymph, which attains its maximum with the complete injection of the yolk and the discharge of the allantoidal blood into the systemic vessels. The infiltrated muscle is physiologically incapacitated from pronounced muscular contraction, and one reason for the marked infiltration is undoubtedly its relaxed condition. The active muscular agent in breaking the shell comes about through a change in the position of

* The Society does not hold itself responsible for the views of the authors of the papers abstracted. The object of this part of the Journal is to present a summary of the papers *as actually published*, and to describe and illustrate Instruments, Apparatus, etc., which are either new or have not been previously described in this country.

the head and upper cervical vertebræ chiefly dependent on musculus biventer and musculus spinalis. The head shifts from the normal egg position of flexed lateral rotation to one of extension more nearly on the vertebral axis. The reflex mechanism which touches off the muscles referred to is probably a respiratory reflex (drinking-choking reflex), not dependent on demand for oxygen, but dependent on distention of the abdomen, particularly the musculus levator ani, brought about through injection of the yolk-sac. The enormous lymph infiltration is a result of rapid absorption, partly due to pressure and partly due to awakened glandular activity, as positive factors, and to the failure of the kidneys to deal with the excess of water, as a negative factor. Not until respiration sets in does the general œdema disappear, which implies that most of the water in birds is excreted by the lungs, and also accounts for the ability of the newly-hatched chick to go at least three days (perhaps four or five) without water. J. A. T.

Hypertrophy of Suprarenal Capsules in Pregnant Rabbit.—J. Watrin (*C. R. Soc. Biol.*, 1919, **82**, 1405–7). The hypertrophy and increased functioning of the suprarenal capsule during pregnancy has been referred by some to the influence of the fœtus, whose waste-products require additional anti-toxins to counteract them. But the hypertrophy is seen also in the thyroid and in the hypophysis, which, the author says, are not known to have an anti-toxic function. On his view the hypertrophy of the suprarenal capsules is a reaction to specific substances secreted by the ovum before its fixation and by elements in the fœtal part of the placenta. Moreover, this reaction does not come about unless the suprarenal capsules have been "sensibilised" by the internal secretion of the corpus luteum. J. A. T.

Nutrition of Mammalian Fœtus from Maternal Blood.—Hassan el Diwany (*C. R. Soc. Biol.*, 1919, **82**, 1235–7). Maternal hæmorrhage in the placenta at a definite time during the gestation has been studied in sheep, ferret, dog, cat, and white mouse. In the first four numerous chorionic villosities enter the hæmorrhagic mass and numerous maternal blood-corpuscles are captured by phagocytosis. Free maternal hæmoglobin is also observed. The chorion cells show biliary pigments in their supra-nuclear portion and fatty droplets towards the base. In the white mouse, cells of the trophoblast degenerate in the midst of the extravasated red blood-corpuscles, and giant decidual cells act as the phagocytes. These giant cells degenerate in turn and their débris is absorbed by the high cylindrical cells which form the visceral wall of the blastodermic vesicle. The "hæmatic embryotrophy," the nutrition from maternal blood, gives the fœtus an abundant supply of iron.
J. A. T.

Testicular Epithelium.—Ed. Retterer (*C. R. Soc. Biol.*, 1919, **82**, 1153–6). In the human embryo and in the child the epithelium of the testis is in cords, in the centre of which lacunæ gradually appear, making a tubule. In the middle of a syncytium of granular cells large spermatocytes appear with clear perinuclear cytoplasm. Each gives

rise to four spermatids. The mitoses in the proliferation of the testicular epithelium are associated with the elaboration of abundant protoplasm. With increase of age the divisions of the seminal epithelium become fewer. The seminiferous tubule becomes a solid band or cord. The intermediate connective tissue increases. The testis is modified in part into islands of fibrous tissue containing cells with clear perinuclear cytoplasm. J. A. T.

Aggregation of Spermatozoa of Sea-urchin in Water in which the Ova have been Macerated.—J. Cotte (*C. R. Soc. Biol.*, 1919, **82**, 1419–21). The spermatozoa converge in groups, as if towards invisible ends. It seems that the "chorion" of the ova becomes dissociated into particles, and it is likely that the spermatozoa hurry towards these as if to ova. J. A. T.

Secretion of Epididymis in Hibernating Bat.—M. R. Courrier (*C. R. Soc. Biol.*, 1920, **83**, 67–9). During the hibernation there is an intense secretion of the epididymis which probably serves for the nutrition of the spermatozoa, large numbers of which are found in the canal of the epididymis. The spermatozoa arrange themselves radially around the large secretory granules. In the testis there is an arrest of spermatogenesis; the seminiferous tubules contain only spermatogonia and Sertoli's nuclei with hardly visible protoplasm. But the interstitial tissue is much developed and in full secretory activity. Probably this endocrine gland conditions the activity of the epididymis. J. A. T.

Spermatogenesis in Anolis carolinensis.—T. S. Painter (*Proc. Amer. Soc. Zool.* in *Anat. Record*, 1920, **17**, 328). In this lizard, "the American chamæleon," what appears to be a typical "accessory" or sex-chromosome is found in the first maturation division; it is bipartite in character and goes undivided to one pole of the spindle. In the second maturation division, the sex-chromosome, when present, divides. The spermatozoa are dimorphic as regards the sex-chromosome; half have it, half are without it. The autosome complex consists of ten large chromosomes and twenty-two smaller bodies. In the first and second spermatocyte divisions five large and eleven small chromosomes are seen (in addition to the sex-chromosome), and these divide in the usual way. There is no "double reduction." There is essential agreement as regards the chromosomes with what occurs in insects and other Invertebrates. J. A. T.

Monsters Produced by X-rays.—W. M. Baldwin (*Anat. Record*, 1919, **17**, 135–63, 2 pls.). Experiments on developing frogs' eggs show that the mitotic routine may be altered, that the cytoplasm is affected as well as the chromatin, that growth and differentiation are affected, that the action of the rays is selective, and that definite changes of a chemical nature in the protoplasmic content of the cells and in their enzymes may be produced by X-ray energy. Experimental evidence at present points to a definite chemical intracellular chemical reaction which may lead to structural abnormalities. J. A. T.

Early Development of Peripheral Nerves in Vertebrate Embryo.—H. H. Lane (*Proc. Amer. Soc. Zool.* in *Anat. Record*, 1920, **17**, 324). The chief nerve trunks are laid down before distinctly nervous functions can be present. In the rat embryo of 23 mm. in length the vestibular and cochlear nerves are well developed, though there is no hearing until about the twelfth day after birth ; in the 16 mm. embryo the vibrissæ have not emerged, yet the maxillaris and mandibularis branches of the trigeminus are well formed. According to Harrison's experiments on the cultivation of tissues *in vitro*, each neurone sends out its axone in a predetermined manner and direction to a distance of a millimetre or so, enough to reach at an early stage, but only at an early stage, to the part it is destined to innervate. J. A. T.

Branchial Segmentation of Cranial Nerves.—N. Betchov (*Révue Suisse Zool.*, 1918, **26**, 233–44, 2 figs.). It is a common usage to refer the trigeminal to the first branchial arch, the facial to the second, the glosso-pharyngeal to the third, and the vago-spinal to the remainder. The author indicates some of the difficulties in this interpretation and proposes another. The trigeminal is the nerve of the buccal cleft. The acustico-facial is associated with the first branchial cleft, the glosso-pharyngeal with the second, the superior laryngeal with the third, the recurrent spinal with the sixth. The fourth and fifth clefts no longer possess special innervation. His interpretation applies directly to mammals. J. A. T.

Development of Pancreas.—Aron (*C. R. Soc. Biol.*, 1919, **82**, 1428–30). A study of the pancreas in embryos of the pig goes to show that the endocrinal gland appears somewhat late in the course of development, and suggests that the embryonic pancreas may have an erythropoïetic function, like the embryonic liver, but more restricted and more accessory. J. A. T.

Development of Thymus, Parathyroid and Ultimo-branchial Bodies in Turtles.—C. E. Johnson (*Proc. Amer. Soc. Zool.* in *Anat. Record*, 1920, **17**, 325–6). In embryos of *Chelydra*, *Chrysemis*, *Trionyx* the thymus arises from the third and fifth visceral pouches. The third also gives rise to a parathyroid body ; this is not the case, at least as a rule, with the fifth. The ultimo-branchial body arises as a secondary diverticulum from an evagination from the pharynx, which also gives origin to the fourth and fifth visceral pouches. The ultimo-branchial body is relatively very large, especially in *Chelydra* ; it is at first nearly equal on the two sides, but that on the right soon lags, and, as a rule, attains only relatively small size. J. A. T.

Influence on Frog's Inter-renal Tissue of Extirpation of the Thyroid and Pituitary Primordia.—Alice L. Brown (*Proc. Amer. Soc. Zool.* in *Anat. Record*, 1920, **17**, 326). In larvæ of *Rana pipiens* twenty-seven months old, from which the thyroid primordia had been removed, the inter-renal tissue remained as irregular, but definite tissue masses about the renal vein. In larvæ, from which the pituitary primordium had been removed, the inter-renal tissue was smaller and less

definite. In all these cases the inter-renal tissue remains in its larval position in relation to the mesonephros—namely, in the form of irregular masses about the renal blood-vessel. J. A. T.

Thyroid and Parathyroid in Toad Tadpoles deprived of Pituitary Body.—Bennet M. Allen (*Proc. Amer. Soc. Zool.* in *Anat. Record*, 1920, **17**, 324–5). Tadpoles without pituitary body, killed six months after the operation, more than four months after the metamorphosis of the controls, showed thyroid one-third of the actual size of normal tadpoles of *Bufo* at metamorphosis, but they showed the normal proportion to the size of the body. The parathyroid glands, on the other hand, showed unusual size, both relatively and absolutely. J. A. T.

Influence of Thyroid Extirpation on Toad Larvæ.—Bennet M. Allen (*Proc. Amer. Soc. Zool.* in *Anat. Record*, 1920, **17**, 325). The removal of the thyroid tends generally to check the differentiation of somatic structures, such as stomach, kidney and bladder. But the gonads are larger and farther advanced in the giant thyroidless tadpoles than in the much younger metamorphosed controls. J. A. T.

Development of Columella auris in Reptiles.—Edward L. Rice (*Proc. Amer. Soc. Zool.* in *Anat. Record*, 1920, **17**, 352–3). The reptilian columella auris has been regarded (*a*) as of otic origin, (*b*) as of hyoid origin, and (*c*) as derived from both. In embryos of *Eumeces* there is evidence of a genetic relation of the proximal portion of the columella to the otic capsule and of the distal portion to the hyoid arch. Yet it seems as if the entire columella was a unit structure. The seeming contradiction may be explained on the assumption that columella, otic capsule, and hyoid arch are all three developed from a continuous embryonic stroma and later differentiated into separate skeletal elements. J. A. T.

Development of Denticles in Sword-fish.—J. Thornton Carter (*Proc. Zool. Soc.*, 1919, 321–6, 3 pls.). The developing denticles in a young *Xiphias gladius* consist of a cap of dentine and a pediment, connected by a transparent area. Later on there is a formation of trabeculæ joining adjacent pediments. The pediments are seen to stand up above the level of the surrounding bone, but this bone continues to thicken and grow until its surface lies almost at the level of the transparent area. The same is true in Blenny, Bream and *Histiophorus*. Tooth or denticle, pediment, and connecting area are formed in all cases on the surface of the same papilla. The bone to which the teeth or denticles are attached is not independently developed, but is "an extension of the denticle cone," so that the sharp line of demarcation drawn by Goodrich between the tooth-bearing bones in Teleostei and the bases of placoid scales does not exist. J. A. T.

Hermaphrodite Green Lizard.—Noel Taylor (*Proc. Zool. Soc.*, 1918, 223–30, 3 figs.). A specimen of *Lacerta viridis* showed testes normal in shape and structure, but bearing stalked outgrowths contain-

ing ova. Besides epididymes and vasa deferentia there were typical oviducts developed for about a third of their lengths. No vasa efferentia were to be seen passing from testes to epididymis. There was on the dorsal portion of one of the kidneys an embedded mass of almost fully grown ova surrounded by follicular cells. The animal must have been physiologically sterile. J. A .T.

Sex Determination in Mammals.—S. Monckton Copeman (*Proc. Zool. Soc.*, 1919, 433–5). Rabbits and some other mammals (pigs, cats, guinea-pigs, mice) were used for experimentation. Semi-castration or semi-spaying (affecting the gonads of one side) and ligature of vas deferens or uterine cornu (on one side) was effected; but there was no demonstrable effect on the sex of the offspring. The number of experiments made is not noted, but it is stated that the few cases (four) of unisexual families (i.e. all male or all female) which were obtained were shown by further experiment to be fortuitous. J. A. T.

b. Histology.

Changes in Nucleolar Substance during Mitosis.—J. Benoit (*C. R. Soc. Biol.*, 1919, **82**, 1431–3). A study of spermatocytic mitoses in mice. After the prophase the nucleoli seem to give rise to nucleoluli, which spread themselves in the nuclear area. These nucleoluli condense and apply themselves to the spireme thread. Each doubles into two daughter-granules, which dispose themselves at the ends of the chromosomes when these are constituted, and migrate with them to the daughter-nuclei. There they form by coalescence a daughter-nucleolus, whose substance is directly due to the parent-nucleolus. There is a nucleolar division as meticulous as the division of the chromatin.

J. A. T.

Varieties of Cartilage.—Ed. Retterer (*C. R. Soc. Biol.*, 1920, **83**, 21–4). Hyaline cartilage is preceded by a stage in which the clear cells are not separated by any matrix. This epithelioid cartilage passes into hyaline cartilage by a thickening of the partitions between the cells. This may pass into bone. The sub-cuboid nodule of the tendon of the long lateral peroneal muscle is connective or fibrous in children and sedentary people; it is vesiculo-fibrous in most adults; it is transformed into a cartilaginous or bony sesamoid in those who perform repeated energetic movements with their legs. In arboreal monkeys this sesamoid passes through a stage of hyaline cartilage and ends as bone. Hereditary predispositions count for something, but the stage which the supporting tissue reaches is in direct relation to the frequency or the intensity of mechanical excitations. J. A. T.

Development of Mastocytes in White Rat.—E. Laguesse (*C. R. Soc. Biol.*, 1919, **82**, 1415–7). Mastocytes (Mastzellen) are very abundant in the newly-born rat, and it seems clear that this crop is due to the transformation of fixed connective tissue cells. They may arise from any mesenchymatous cell. In certain tissues which retain in

part the properties of the primitive mesenchyme (osseous medulla) there arises a specially mobile variety, the myelocyte, and afterwards the basophilous leucocyte. The latter, after diapedesis, may become a fixed basophilous cell, probably a clasmatocyte. J. A. T.

Structure of the Duodenum in Mammals.—F. VILLEMIN (*C. R. Soc. Biol.*, 1919, **82**, 1426–8). The duodenum in man and in those mammals with the openings of the bile duct and pancreatic duct at the same level (monkey, some rodents, carnivores, some herbivores) may be divided into two portions, an upper, down to the apertures, and a lower, beyond the apertures. The upper portion is dilated, with a thick wall, with arteries from the hepatic only, and with Brunner's glands. The lower portion is like a jejunal loop; it receives branches from the superior mesenteric; it has no Brunner's glands. In the mammals mentioned above Brunner's glands are of the mucous type.
J. A. T.

Types of Duodenum in Mammals.—F. VILLEMIN (*C. R. Soc. Biol.*, 1920, **83**, 65–7). In the ox the bile duct opens far from the pylorus; the pancreatic duct below the bile duct at a relatively short distance from it. In the pig the bile duct opens near the pylorus; the pancreatic duct as before. In the rabbit the bile duct opens very near the pylorus, and the pancreatic duct far from the pylorus at the end of the duodenum. There are these three types. Brunner's glands, whether mucous or mixed, extend to the opening of the pancreatic duct, but never further, whatever be the distance of the aperture from the pylorus.
J. A. T.

Structure of Sphincter Muscles in Man.—A. LACOSTE (*C. R. Soc. Biol.*, 1920, **83**, 41–3). In sphincters with striped muscle-fibres, such as those in the ureter and around the anus, each fibre has a thick connective sheath, formed of connective and elastic fibres. The muscle-fibres are surrounded by a plexus of elastic fibres, mostly perpendicular to, or obliquely disposed to, the lie of the muscle-fibres. It is probable that the intervention of the connective tissue between the fibres gives the latter a "point d'appui" in the absence of fixed bony points.
J. A. T.

Plexiform Sphincters of Smooth Muscle in Alveolar Canals and Pulmonary Acini of Mammals.—G. DUBREUIL and P. LAMARQUE (*C. R. Soc. Biol.*, 1919, **82**, 1375–7). The muscles of the terminal bronchioles are continued on the alveolar canals by smooth muscle-fibres which form a plexus. This plexus surrounds by its meshes the lumen of the alveolar canals, forming a sphincter for each. J. A. T.

Regenerative Growth of Striped Muscle-fibres after Traumatic Lesion.—J. NAGEOTTE and L. GUYON (*C. R. Soc. Biol.*, 1919, **82**, 1364–7). It was observed that a piece of glycerinated nerve introduced between the two ends of a cut muscle was invaded by newly formed striped muscle-fibres. J. A. T.

Endocrine Gland in Uterus of Pregnant Rat.—P. Weill (*C. R. Soc. Biol.*, 1919, **82**, 1433–5). A description of large glandular cells clustered round the capillaries of the uterine myometrium. Cytologically they seem referable to the connective-tissue type of cell, but they are distinctly secretory, elaborating eosinophilous granulations. They form a perivascular endocrine gland. J. A. T.

Cortical Layer of Simple Teeth.—Ed. Retterer (*C. R. Soc. Biol.*, 1919, **32**, 1222–5). The cortical layer or cement is ossified in the same way as the periosteum or tendons. Connective-tissue cells become first vesicular and then bony; they are transformed into cementoblasts or corticoblasts. This transformation takes place under conditions of pressure. The corticoblasts are oval or rounded cells, with clear cytoplasm; they are encapsuled, and the capsule is surrounded by granular non-calcified cytoplasm. J. A. T.

Dust Cells in Pulmonary Alveoli.—A. Guieysse-Pellisier (*C. R. Soc. Biol.*, 1919, **82**, 1215–7). A study of stages of transformation convinces the author that the dust cells found free in the pulmonary alveoli are greatly modified epithelial cells, adapted to a phagocytic function. J. A. T.

Fat in Pulmonary Epithelium.—F. Granel (*C. R. Soc. Biol.*, 1919, **82**, 1367–9). A study of the epithelium of the alveoli and of the terminal bronchial ramifications. There is in the small nucleated cells a transformation of mitochondrial granules into fat. In fact these cells may be fairly called glandular, producing granules of a fatty nature which may possibly play a part in fixing certain substances. This may be of interest in connection with Bohr's theory that the gaseous exchanges in the lung are more allied to secretory activity than to osmotic diffusion. J. A. T.

Supporting Tissue of Human Liver.—R. Collin (*C. R. Soc. Biol.*, 1920, **83**, 78–80). The supporting tissue of the liver is much reduced in man; it consists essentially of the interlobular connective tissue, of the adventitia which surrounds the central vein of the lobules, and of the trellised fibres forming an intralobular system, connecting the interlobular connective tissue and the adventitia. It seems subordinated to the disposition of the blood-vessels. J. A. T.

c. General.

Cross Immunization.—L. Camus and E. Gley (*C. R. Soc. Biol.*, 1919, **82**, 1240–1). Rabbits immunized against the serum of *Muræna* resisted that of *Anguilla*, and *vice versa*, there being reciprocal immunization. The authors have already shown that rabbits immunized against the serum of *Anguilla* are also immune to that of the conger-eel. But rabbits immunized against eel serum are not immune to that of the Torpedo, nor *vice versa*. J. A. T.

Physiological Inertia and Physiological Momentum.—D. Fraser Harris (*Scientific Monthly*, 1919, 539–49). Functional or physiological

inertia is that property of living matter in virtue of which, having received a stimulus, it continues to maintain the functional *status quo ante*, whether that was activity or inactivity; and functional momentum is that property of bioplasm in virtue of which the living matter, having responded to a stimulus, continues to exhibit its activity or inactivity after the stimulus has ceased to exist. Functional or physiological inertia is that property of living matter which maintains the *status quo ante*, namely, non-response to a stimulus tending to arouse a response (functional inertia of rest), or response after the stimulus has ceased (functional momentum). Affectability is that property of living matter in virtue of which it responds to a stimulus either by activity or by the quelling of activity (inhibition). Protoplasmic inertia is the physiological counterpart of affectability. J. A. T.

Immunity and Anaphylaxis.—MAURICE ARTHUS (*C. R. Soc. Biol.*, 1919, **82**, 1230–2). Nolf has suggested, on the ground of some interesting experiments, that immunity and anaphylaxis are two manifestations of the same organic state. Arthus reports other experiments, chiefly with rabbits in relation to snake-poison, which go to show that the two states are quite distinct and may exist simultaneously in the same animal. J. A. T.

Hereditary Brachyphalangy.—OTTO L. MOHR and CHR. WRIEDT (*Public. Carnegie Inst. Washington*, 1919, **295**, 1–64, 7 pls.). A symmetrical shortening of the second phalanx of the second fingers and toes inherited within a Norwegian family, some members of which emigrated to North America. The peculiarity is restricted to one phalanx; the other parts are normal; the individuals show no shortness of stature. The anomaly manifests itself as "slightly" shortened and as "much" shortened, but there is no intermediate condition. There is no premature ossification of the epiphysial cartilage. The inheritance is followed without any break through six generations, including and descended from an individual born in 1764. The brachyphalangy is inherited as a dominant, not sex-linked character. All the brachyphalangous individuals are heterozygous for the gene in question, with one possible exception. The material included a case of identical twins, both brachyphalangous of an identical type. The two types, "slightly" and "much" shortened, are explained through the presence in some of the normal individuals, married into the family, of a dominant specific modifying gene which enhances the effect of the principal gene for brachyphalangy, and changes the "slightly" into the "much" shortened type. J. A. T.

Homologies of Squamosal of Fishes.—EDWARD PHELPS ALLIS, Jr. (*Anat. Record*, 1919, **17**, 73–87). The squamosal of fishes, frequently called the pterotic, is primarily a dermal bone which develops along the dorsal surface of the ridge of the lateral semicircular canal. Anteriorly it articulates with frontal or parietal or both. The summit of the post-orbital process ossifies as the sphenotic or dermosphenotic. Both acquire primary relations with the chondrocranium, and may be composed of

external and internal plates enclosing the fish's temporal fossa, corresponding to part of the temporal fossa in mammals. The cerebral portion of the squamosal in man and the zygomatic process are derived from the sphenotic of fishes or that bone fused to the pterotic. The auricular portion of the squamosal corresponds to the cheek-plate of fishes. The tympanic of mammals and the quadrato-jugal of amphibians and reptiles correspond to the pre-operculum of fishes. The jugal corresponds to a fusion of some sub-orbital bones in fishes, and the post-orbitals of fishes fuse with the maxilla to form the maxilla of mammals. There are apparently four distinctly different temporal arches in Vertebrates: one formed by the dermosphenotic and post-orbital (man, upper arch in Hatteria and Crocodile); one formed by the cheek-plate of fishes and the post-orbital or jugal (Lacerta, Scleroporus, part of lower arch of Hatteria); one formed by the quadrato-jugal and jugal (lower arch of Crocodile, part of lower arch of Hatteria); and one formed by the quadrato-jugal and maxilla (Amphibians). J. A. T.

Reputed Endocrine Function of Thymus Gland.—Matsuziro Takenouchi (*Journ. Exper. Zool.*, 1919, **29**, 311–42, 2 charts). Experiments with thymus substance of the albino rat, mainly by means of serum obtained from rabbits immunized with the thymus substance, yield very negative results. "So long as we are unable to maintain a more solid foundation, we cannot accept the specific action of the antithymus serum, nor, furthermore, can we believe [in] any endocrine function whatever of the thymus gland, no matter whether the cortical or medullary portion play the principal rôle in the physiological function of this gland."
J. A. T.

Locomotion in a Spiral.—A. A. Schaeffer (*Proc. Amer. Soc. Zool.* in *Anat. Record*, 1920, **17**, 342). So far as the author's observation goes, all motile plants and animals, when not guided by orienting senses, are influenced, when freely moving, by some agency so that the resulting path resembles some form of spiral. The great diversity of form exhibited by organisms that move in spiral paths indicates that the automatic mechanism regulating the direction of the path is not dependent upon or connected with structure, but is much more fundamental in its nature, affecting the protoplasm directly. J. A. T.

Cerebral Function in Learning.—K. S. Lashley (*Psychobiology*, 1920, **2**, 55–128, 4 pls.). There is complete vicarious functioning of all parts of the rat's cerebrum in learning. This seems to hold true both for the cortex and for the underlying structures making up the archipallium. Learning may go on with equal speed in the presence or absence of particular specialized areas. There is strong evidence against there being special cerebral areas that have a directive influence over learning, whether it be by "attention," mediated through the frontal lobes, or by the "conscious action" of the brain as a whole. On the contrary, Lashley's results suggest that the only essential condition for learning is the simultaneous activity of two reaction systems which are

in anatomical connexion by association fibres. Within certain limits there is no relation between the amount of cerebral material functioning and the rate of formation of complex habits. In normal rats the habit of brightness discrimination is mediated by the occipital pole of the cerebrum (area striata), and by no other part of the cerebral cortex.

J. A. T.

Ear of Guinea-pig.—GEORGES PORTMANN (*C. R. Soc. Biol.*, 1919, **82**, 1384–6, 1 fig.). This differs from the ordinary mammalian type. There is a median dumb-bell-shaped portion with a very narrow connecting tube (the endolymphatic canal), two gradually expanding ends, one of them intracranial (the endolymphatic sac, in close relations with the lateral sinus), the other vestibular (the sacculus). From the sacculus a very straight and short canalicule establishes communication with the utriculus, and a larger one leads to the cochlear canal. In passing from the sac to the saccule there is a gradual flattening of the epithelium and a progressive development of perilymphatic spaces. The endolymphatic sac is in intimate relations with the intracranial venous system. J. A. T.

Endolymphatic Sac and Duct in Dog.—GEORGES PORTMANN (*C. R. Soc. Biol.*, 1920, **83**, 45–8, 1 fig.). The author's description of the inner ear of the dog does not agree with what is believed to be usual in mammals. The membranous internal ear shows a median dumb-bell-like portion, with unequal expansions. The narrow median isthmus is the endolymphatic canal. One gradually expanded end, the larger one, lies intracranially, the endolymphatic sac, which is in intimate relations with the lateral sinus. The other end, the smaller, is vestibular, and is the sacculus. From the sacculus, and from about the same level, two canaliculi arise, the upper one communicating with the utriculus, the lower one with the cochlear canal. Emphasis is laid on the following facts:—The endolymphatic sac is relatively very large; its connexion with the lateral sinus is intimate and extensive; the epithelium is gradually flattened, and the perilymphatic spaces are increasingly developed in passing from the sac towards the sacculus. J. A. T.

Distribution of Parasitized Fish.—H. CHAS. WILLIAMSON (*Ann. Applied Biol.*, 1919, **6**, 48–52). What are called "spotted haddocks" show in the muscles numerous cysts of a Protozoon parasite, *Dokus adus*. They have an unpleasant smell (suggestive of creosote), and are said to have a sour taste. They seem to have a restricted geographical distribution, about Shetland and west of Orkney, but the evidence is not very convincing; they are absent from Faroe. Similarly, "worm-infested codlings," with numerous very-resistant Nematodes (like young stages of *Ascaris decipiens*), coiled up in the muscles (able to survive brine-pickle for half-an-hour and smoking for three-quarters of an hour or more), do not occur at Shetland but at Faroe. It may be that local environmental factors account for the diverse distribution of certain kinds of parasitized fish. J. A. T.

INVERTEBRATA.

Mollusca.

γ. Gastropoda.

Radula of Mitridæ.—A. H. Cooke (*Proc. Zool. Soc.*, 1919, 405–22, 18 figs.). The rhachidian tooth exhibits wide differences in structure, ranging from the lozenge-shaped 8- to 9-cusped form in *Mitra* to the unicuspid triangular form of the *variegata* group. These divergences in the structure of the rhachidian are accompanied by a general similarity of plan in the laterals, subject however to a progressive modification in their form. The laterals, in fact, exhibit every symptom of regress towards a gradual degradation. Perhaps there is a clue here to the genesis of the familiar bicuspid or unicuspid lateral of many of the Rhachiglossa. It seems within the bounds of possibility that the coalescing, or gradual disappearance, of the cusps, in a multicuspid lateral, produced in more cases than that of the Mitridæ a lateral with one or two large cusps instead of many small ones. J. A. T.

Sensory Reactions of Chromodoris zebra.—W. J. Crozier and Leslie B. Arey (*Journ. Exper. Zool.*, 1919, **29**, 261–310, 8 figs.). Experiments on mechanical, photic, thermal and chemical excitation of this Nudibranch. There are differentiated receptors mediating reactions to tactile, chemical and shading stimulation, to the constant intensity of light, and perhaps to heat. Locally, the responses of the general integument and all the outgrowths depend upon locally contained, peripheral, non-synaptic networks, which are polarized in the gill-plumes and probably in other projecting parts. Reactions involving parts distant from the site of activation depend upon central, ganglionic transmission. The central nervous system is essentially synaptic. The Nudibranch is positively phototropic, the chief receptive organs probably being the eyes, but the gill-plumes are also sensitive, expanding in light, retracting when shaded. When sexually mature, the animal is negatively geotropic. It is negatively rheotropic to strong water currents, the directive organs being the "rhinophores." Chemotropic reactions to body secretions of other individuals lead to conjugation, "olfactory" and "gustatory" stimulation being concerned. The locomotion is primarily muscular, not ciliary. The outer lateral margins of the foot are active. The foot is positively stereotropic, and when removed from a surface folds together laterally. This suits creeping on narrow blades of eel-grass. The stereotropism of the anterior end of the foot is responsible for righting behaviour. There is no apparent statolithic control for dorso-ventral body orientation. J. A. T.

Sensory Responses of Chiton.—Leslie B. Arey and W. J. Crozier (*Journ. Exper. Zool.*, 1919, **29**, 157–260, 14 figs.). An account of the general natural history of *Chiton tuberculatus*, its movements and reactions, and its responses to mechanical, thermal, photic, and chemical excitation. The sensory conditions are unexpectedly complex; the

major pathways of nervous transmission are, by contrast, unusually clear and well defined. (*a*) Tactile receptors are absent from the shell surfaces. The "scales" and "hairs" upon the girdle are important tactile organs. The ctenidia are also sensitive to touch, as are the proboscis, the foot, and the ventral surface of the girdle. The foot is positively thigmotactic to large surfaces, but retracts locally when stimulated by a small surface. The tegmental æsthetes are photosensitive; they are activated by light of constant intensity and by sudden decrease in light intensity, not by increase. The dorsal surface of the girdle, the soft ventral surfaces and the periphery of the girdle are sensitive to light. The superficial soft tissues are open to chemical activation, to stimulation by abnormal osmotic pressures, and by "irritants." Tactile, photic, and chemo-receptors are physiologically distinct. There is no clear evidence of sensitivity to heat; that to cold is less doubtful. There is a pronounced tendency for the animal to come to rest in positions avoiding uneven tensions in the musculature. This is responsible for the precise negative geotropism exhibited by Chiton. It is not sensitive to vibratory mechanical disturbances. (*b*) The problem of differential irritability is difficult. One factor is anatomical isolation of particular receptors (e.g. removal from the external surface). Another is the structure of the receptor. An additional factor is probably found in the possession by certain receptor cells of special substances which enter into excitation reactions. On the sole of the foot of Chiton there is evidence of separate photo-, tacto-, and chemo-reception. Even if the epithelial cells of an animal were open to sensory activation by a variety of stimuli, it would not be legitimate to argue to a primitive "universal" kind of receptor. (*c*) The reactions of Chiton to local stimulation are of a character consistent with the known distribution of the central nervous system. The responses of isolated portions of an animal cut transversely are such as to show the absence of any strong centralization. This is in agreement with the known occurrence of ganglion cells throughout the whole length of the nerve strands. (*d*) The young Chiton is photo-negative, the old Chiton photo-positive, to sunlight. There is a progressive age change, which is connected with the erosive destruction of the photo-sensitive æsthetes. The erosion of the shell is due to growth effects and to organisms settling down on it. (*e*) The homochromic coloration of Chiton is determined by the algal food and by organisms on the shell. A homochromically coloured Isopod is a characteristic companion. Various harmonious correlations follow automatically in the wake of the changing phototropism of Chiton. The animal's habits determine the environment in which it lives. J. A. T.

Homing of Limpet.—HENRI PIÉRON (*C. R. Soc. Biol.*, 1919, 82, 1227–30). The limpet shows a topographical memory for its site. It feels the surface of the rock with its cephalic tentacles, and to some extent by its pallial tentacles. But there is also a kinæsthetic memory. There are two other factors which operate in the homing—namely, gravity and illumination—but these are secondary compared with the topographical data afforded by touch on rough surfaces. J. A. T.

Arthropoda.

α. Insecta.

Study of Ammophila heydeni.—E. Rabaud (*Bull. Soc. Zool. France*, 1919, **44**, 52–63). Description of the behaviour of this digger-wasp. In beginning to burrow the insect holds firmly with the second and third pairs of legs, uses her head and fore-legs, and vibrates her wings rapidly. The earth is carried out in the mandibles, sometimes by flight, sometimes afoot. There is considerable elasticity. After depositing a paralysed caterpillar, the wasp lays an egg on the side of the victim; and then another caterpillar may be brought in and no egg laid. Sometimes five or six caterpillars were collected. There is more plasticity than some observers have admitted. The position of the burrow is found after a flight by motor-memory; but when the mouth of the furrow was concealed the wasp was sometimes baffled. Though she returned to the situation (by motor-memory), she could not always find the disguised doorway. This points to a sensory memory. With few exceptions the wasp kept to the same species of caterpillar. This involved extra hunting, and its utility is not obvious, for Fabre showed that the wasp-grubs can thrive on various sorts of food. The use of the paralysing is not very clear, for the wasp-grubs can thrive on dead caterpillars, and they do often die. The results of putrefaction seem to be trivial. J. A. T.

Reactions of Bees to Light.—Dwight E. Minnich (*Journ. Exper. Zool.*, 1919, **29**, 343–425, 17 figs.). Light exerts a kinetic influence in honey-bees; it tends to induce activity. In its absence activity is greatly reduced or is entirely lacking. Isolated worker-bees, in an active condition, exhibit strong positive phototropism when flying or creeping. Temporary suppressions of this response may occur, however. Normal bees creeping in non-directive light often move asymmetrically, probably for internal reasons, for the same occurs in darkness. Bees with one eye blackened usually loop towards the functional eye as they creep toward a source of light. In non-directive light they generally circle toward the functional eye; this is more marked in more intense illumination. The cause is the continuous unilateral stimulation. Variability of response may be accounted for in many ways. Photic orientation in the normal honey-bee is effected through the continuous action of light on both photo-receptors. Orientation to light in Arthropods generally is effected through the continuous action of the stimulus rather than through intermittent changes of its intensity. J. A. T.

American Insect Galls.—E. P. Felt (*Bull N. Y. State Museum*, 1918, **200**, 1–310, 16 pls., 250 figs.). A very useful finely illustrated key to American Insect Galls and Mite Galls, arranged under the plants on which they occur. No fewer than 1,441 insects are included, 682 being gall midges and 445 gall wasps. Besides these there are other Diptera and Hymenoptera, besides various Coleoptera and Hemiptera.

There are 161 species of mites (Eriophyidæ) on the list. The irritant causes recognized are fluids in the egg or injected with it, secretion from the larva, mechanical stimulation by the gall-maker itself. J. A. T.

Plant Galls of Philippines.—LEOPOLDO B. UICHANCO (*Philippine Journ. Sci.*, 1919, **14**, 527–54, 15 pls.). An account of 57 zoocecidia due to Rhynchota (Psyllidæ, Aphididæ and Coccidæ), Diptera (Itonididæ or Cecidomyidæ and Trypetidæ), Hymenoptera (Cynipidæ and Tenthredinidæ), Lepidoptera (Gelechidæ), Coleoptera (Buprestidæ), Thysanoptera, and Eriophyid mites. It is noted that the gall of animal origin may be occasionally a response to severe mechanical injury or to continuous mechanical irritation, but is mainly due to a secretion either at the time of oviposition or during the development of the insect. Moliard (1917) removed some of the secretion of the larva of *Aulax papaveris*, a Cynipid gall-maker on the pistil of *Papaver rhœas*, and injected it into the growing pistil of the poppy, where galls were evoked like those produced by the larva itself. Euphorbiaceæ and Moraceæ seem to furnish in the Philippines more galls than any other orders do. Galls can be produced only when the tissue of the plant is still developing. After the plant tissue has been fully matured no amount of stimulus will evoke a gall. J. A. T.

Emergence of Larvæ of Apanteles glomeratus from Caterpillars of Pieris brassicæ.—CL. GAUTIER (*C. R. Soc. Biol.*, 1919, **82**, 1369–71). The parasitized caterpillars never attach themselves as the normal ones do when they pass into the chrysalid stage. The larvæ bore out almost simultaneously, emerging mostly on the sides above the pro-legs. But a few may come out on the back, and very rarely on the ventral surface. They form cocoons in one mass below the caterpillar, or in two groups. These are in part attached to the caterpillar's chrysalid threads. The caterpillar may be found dead above or among the cocoons, or it may actually move with its burden to some distance, where it dies. Before it dies, however, it makes a new and thick feltwork of filaments around the cocoons of the parasites. Caterpillars from which the larvæ have emerged never eat and never form an actual chrysalis. Fabre described the issue of the parasites by a single aperture, but Gautier and others describe each parasite emerging by its own aperture. J. A. T.

Food of Caterpillars of Pieris and Euchlöe.—CL. GAUTIER and PH. RIEL (*C. R. Soc. Biol.*, 1919, **82**, 1371–4). Fabre laid emphasis on the fact that the caterpillars of *Pieris brassicæ* require Cruciferous plants, but as a matter of fact they may also eat Tropæolum. Their relatives may likewise feed on members of the families Tropæolaceæ, Resedaceæ, Myrtaceæ, Araceæ, Papilionaceæ, Crassulaceæ, and Capparidaceæ. In short, the caterpillars are more "polyphagous" than has been supposed. Guignard has shown a chemical affinity between Cruciferæ, Tropæolaceæ, Capparidaceæ, and Resedaceæ, for most of them show the presence of myrosin and sulphurous glucosides. The butterflies are probably directed mainly by the odour to plants suitable for the nutrition of the caterpillars. J. A. T.

Notes on Common Flies.—G. S. Graham-Smith (*Parasitology*, 1919, **11**, 347–84, 2 pls., 23 figs., 2 charts). The curve indicating the number of flies caught in a trap baited with excrement corresponds with the curve for maximum temperature recorded by a thermometer exposed in the sun. Flies spend a very large proportion of their time in cleaning themselves and usually follow a definite routine. Empusa disease occurs in a good many species. Certain Gamasid mites destroy both fly eggs and young larvæ. Certain species of beetles destroy large numbers of fly puparia. Numerous parasites were obtained from naturally infected fly puparia, especially species of Chalcididæ and Braconidæ. The Chalcid *Melittobia acasta* frequently parasitizes puparia already infected with the Braconid *Alysia manducator*. The males, which are blind, unable to fly and relatively few in number, reach maturity before the females in the same puparia, and the stronger specimens destroy the weaker. The males never leave the puparia in which they hatch, but mate with the females before the latter escape from the puparia. Fertilized females lay large numbers of eggs from which a few males and numerous females develop. Virgin females only lay a few eggs, from which males develop. If fertilized subsequently, numerous eggs are deposited which develop into both males and females. These parasites oviposit in puparia, not in larvæ. The Brachonid *Alysia manducator* attacks large larvæ; some of the imagines emerge in spring and others in autumn, one from each puparium. Virgin females lay numerous eggs which develop into males. J. A. T.

Mosquitoes.—F. W. Edwards (*Publications British Museum, Nat. Hist.*, 1916, *Economic Series*, **4**, 1–19, 6 figs.). An admirably clear and terse account of the general characters and life-history of mosquitoes, which are grouped for practical purposes as domestic, stream and pool, sylvan, and swamp mosquitoes. The distinctive features of the *Anopheles* mosquitoes are discussed, and the relations of mosquitoes to malaria, yellow fever and elephantiasis are briefly dealt with. Practical measures are also discussed. J. A. T.

Anopheles crucians.—C. W. Metz (*Reports U.S. Public Health Service*, 1918, **495**, 2156–69). This species occurs along with *A. punctipennis* and *A. quadrimaculatus* in the gulf coast region of the United States. It is a swamp mosquito; it seemed to live on non-living vegetable débris; it was breeding prolifically at the beginning of April and continued breeding until late summer at least; it will become distributed over an area within approximately 7,000 feet of the source. J. A. T.

Sense-Organs in Antennæ and Palps of Diptera.—K. M. Smith (*Proc. Zool. Soc.*, 1919, 31–69, 4 pls., 43 figs.). An interesting comparative study, very abundantly and clearly illustrated, of "sense-pits" and similar structures. Each component element consists of a large, modified, hypodermal cell, above which is a very thin-walled chitinous process, rising from the thicker chitin of the general surface, and of a nerve-fibre which runs close up to the base of, if not actually into, the

chitinous process. A typical sense-pit shows an opening in the chitin leading down into the pit itself, frequently a channel with spiral folds or various ridges, and a floor produced into the sensory processes which rise like the fingers from a glove. Below the floor is a rounded mass of large radiating cells, each shell separating from its fellow as it approaches the base of the pit and running to its corresponding sensory process. The whole mass of cells is embraced by a branch of the large antennary nerve. In an appendix Prof. H. M. Lefroy suggests that the function of the structures is purely olfactory, that the general surface of the antennæ acts for delicate perceptions, that the pits come into play when the concentration of the absorbed liquid has dulled the simple organs on the outer surface, and that the final location of the source of scent is due to the protected pits. Further, it is suggested that the presence of two kinds of pits in some species is correlated with the dual perception in the female of food and of breeding-place; in the male, of food and of the female. J. A. T.

Horned Littoral Fly.—L. Mercier (*C. R. Soc. Biol.*, 1919, **82**, 1217–18). A specimen of *Fucellia maritima* Hal. showed a minute horn between the eyes, and Villeneuve suggested that this was due to a hardening and persistence of the frontal vesicle, which is protrusible and contractile on the head of the young flies; experiments corroborate this. The larvæ pupate in the sand under clumps of seaweed, and some which may find it difficult to get free may show a horn. J. A. T.

Flies in Snails.—D. Keilin (*Parasitology*, 1919, **11**, 430–55, 4 pls., 6 figs.). The fly *Melinda cognata* Meigen has its young stages in the small snail *Helicella virgata*. The oviposition was not observed. The larva occurs first in the kidney, which it destroys, and then in the mantle cavity. It kills the snail and pupates in the earth. There are several hyperparasites of *M. cognata*, notably two Ichneumonids (*Atractodes exilis* and *Exolytus petiolarius*) which oviposit in *Melinda* larvæ while still in the snail. The early stages of *Melinda* are described. Three other flies were found in *Helicella*—viz. (1) another species of *Melinda*, probably *M. gentilis*; (2) *Sarcophaga nigriventris*; and (3) another species of *Sarcophaga*, probably *S. crassimargo*. Finally, the author sums up what is known as to parasitic, carnivorous, epizoic, and saprophagous Diptera occurring on living and dead molluscs. J. A. T.

Photic Orientation in Drone-Fly.—S. O. Mast (*Proc. Amer. Soc. Zool.* in *Anat. Record*, 1920, **17**, 344). It has been maintained that photic orientation depends on the fact that unequal illumination of the two eyes means a difference in the tonus of the muscles of the legs on the two sides of the body. The body, in response to the unequal tonus, is turned until the two eyes are equally illumined. But if the two front legs on one side are removed, orientation is nearly as precise as it is in normal specimens, showing that orientation is not necessarily dependent upon the relation in tonus in the muscles of the legs on opposite sides. If one eye is covered, orientation may still occur. If the two front legs on one side are removed and either eye is covered,

proper unilateral illumination may still induce turning either to the right or the left, showing that the movements of the legs may be controlled by impulses received from either eye. Moreover, the response depends in part upon the location of the stimulus on the eye, and not solely upon the magnitude of the stimulus. In short, the process of orientation may be more complicated than is implied in the theory of unequal illumination and resulting difference of tonus. J. A. T.

Oviposition of Gastrophilus nasalis.—A. E. CAMERON (*Science*, 1919, **49**, 26). It is denied that this bot-fly darts at a horse's lips and leaves eggs there, as C. H. Townsend stated. The eggs of *G. nasalis* are deposited on hairs of the throat. The adult fly strikes at the hairs of the skin between the mandibles, and sometimes on the hairs of the cheek. The clasping stalk of the egg of *G. hæmorrhoidalis*, which is invariably found attached to the short hairs of the lips, often appears to penetrate the skin. This is not really the case, but the clasping stalk may sometimes enter the hair follicle. J. A. T.

Behaviour of Larvæ of Corethra punctipennis.—CHANCEY JUDAY (*Proc. Amer. Soc. Zool.* in *Anat. Record*, 1920, **17**, 340). In the deeper portions of Lake Mendota these larvæ are very abundant; more than 30,000 per square metre have been noted. The larger larvæ burrow during the day in the mud (in anærobic conditions for two months in summer); at night they occupy the water, and may ascend to the surface —a vertical migration of 25 metres. The pupæ do the same. The small larvæ occupy the lower water in the daytime for a week or two, migrating upwards at night. J. A. T.

Olfactory Sense in Orthoptera.—N. E. McINDOO (*Proc. Amer. Soc. Zool.* in *Anat. Record*, 1920, **17**, 341–2). In grasshoppers and crickets there are olfactory pores on the first and second segments of the antennæ. When the antennæ are cut off through the third segment the reaction time to odours is increased. The average reaction time of the intact grasshoppers is 8·4 seconds, after mutilation 9 seconds. The average reaction time of the intact crickets is 8·8 seconds, and after mutilation 10·2 seconds. J. A. T.

Variation in Venation of Panorpa communis.—L. MERCIER (*C.R. Soc. Biol.*, 1919, **82**, 1168–70). The radial nervure in the genus *Panorpa* has a single sector, which often gives off four branches, and often three in *P. communis*. The character may be regarded as at present quite unfixed. J. A. T.

Bed-bug.—BRUCE F. CUMMINGS (*Publications British Museum, Nat. Hist., Economic Series*, 1918, No. 5, 1–20, 7 figs.). A very clear account of the external structure and the habits of *Cimex lectularius*, with particular reference to its mode of sucking blood. The life-history is sketched, and the possibility that it spreads disease-germs is discussed. The blockage of the gut with bacteria that occurs in the rat-flea is not likely to occur in the bed-bug; so it is not very probable that the transmission of diseases by bed-bugs is of general occurrence. Remedies are duly dealt with. J. A. T.

Incubation of Eggs of Horse-lice.—A. BACOT and L. LINZELL (*Parasitology*, 1919, **11**, 388–92). Three kinds of lice are found on horses—*Trichodectes equi* and *T. pilosus* (Mallophaga), and *Hæmatopinus asini* (one of the Siphunculata). The eggs of the last-named species may take a month or more to hatch, therefore the last dressing should be given not less than thirty-four days after the time the treatment started. The minimum time for development from hatching to the fertile female is probably about a fortnight. If the dressing is repeated at ten-day intervals there should be at least four dressings. The normal incubation period would appear to be sixteen to twenty days; the minimum in natural conditions about fifteen to sixteen days. A very small amount of *dry* heat is fatal to the eggs. Moist cold also kills, but dry cold lengthens out the incubation period. J. A. T.

Systematic Questions concerning Lice.—GEORGE H. F. NUTTALL (*Parasitology*, 1919, **11**, 329–46). The name Anoplura Leach (1817) was originally applied to both Siphunculata and Mallophaga, and it should be still used in that sense. Diagnoses are given of the order Anoplura, the sub-orders Mallophaga and Siphunculata, the four families of Siphunculata (Pediculidæ, Hæmatopinidæ, Echinophthiriidæ, and Hæmatomyzidæ), and the genera *Pediculus* and *Phthirus*. Morphological and biological evidence is submitted showing that *Pediculus capitis* and *P. corporis* merely represent two *unstable races* of one species, *P. humanus* Linnæus. J. A. T.

Mallophaga from Formosan Birds.—SEINOSUKE UCHIDA (*Annot. Zool. Japon.*, 1920, **9**, 635–52, 3 figs.). Twenty-six species are described, three new, including *Comatomenopon elongatum* g. et sp. n. from a tern. It is an elongate translucent form, showing in both sexes

Gastric teeth of *Comatomenopon elongatum* g. et sp. n. × 230.

a dense row of dark-coloured teeth at the distal end of the crop. This is the second case known of the presence of gastric teeth in the Mallophaga, the first case having been reported by B. F. Cummings in *Trimenopon echinodermata* from *Cavia aperea*. J. A. T.

New Mallophaga from South African Birds.—G. A. H. BEDFORD (*Parasitology*, 1920, **12**, 167–72, 2 pls.). A description of *Machærilæmus plocei* sp. n. from a waxbill, and *Neomenopon pteroclurus* g. et sp. n. from a sand-grouse. The head of the new genus has distinct and fairly deep

ocular emarginations; it is very broad, more than twice as wide as long; the temples are large. There is no chitinous plate on the throat, but there is a chitinous framework for the support of the mandibles. The prothorax has its lateral margins rounded. The mesothorax is fused to the metathorax. The pleurites are well-developed. J. A. T.

Head and Mouth-parts of the Apple-sucker.—A. J. Grove (*Parasitology*, 1919, **11**, 456–88, 3 pls., 1 fig.). Description of *Psylla mali* as regards the exoskeleton of the head (the head-capsule, the buccal region and labium, the setæ, and the hypopharynx), the endoskeleton of the head (the tentorium, the salivary pump, and the pharynx), and the complex musculature concerned. In regard to the mechanism of piercing, it is shown that this cannot be due to the action of the protractor muscles, and it is suggested that the setæ are forced into the host through the agency of the labium, actuated by variations in the internal pressure of the body-fluid contained within it. A raising of the thorax when the labium is in a state of turgescence, and consequently has a firm grip of the setæ, will withdraw the setæ from the wound. As regards the mechanism of sucking, it is suggested that the sap rises in the suction-canal by means of capillarity. The injection of the salivary secretion into the host by the propulsive force exerted by the salivary pump is also discussed. J. A. T.

Food-canal of Cicada.—C. W. Hargitt and L. M. Hickernell (*Proc. Amer. Soc. Zool.* in *Anat. Record*, 1920, **17**, 351–2). There is a well-differentiated and continuous digestive tube in the adults of both sexes. The alleged discontinuity is not confirmed, but there is a thinning of the digestive epithelium as adult life proceeds. At the posterior end of the relatively short and narrow œsophagus there is a valve which marks the beginning of the crop. Following the crop proper there is an anteriorly directed coil of intestine with Malpighian tubules. The coil lies just dorsal to the crop. Thereafter the intestine runs dorsally to the seventh abdominal segment where it opens into the rectum. J. A. T.

Vision in Cicada septendecim.—S. O. Mast (*Proc. Amer. Soc. Zool.* in *Anat. Record*, 1920, **17**, 345). When the "pupæ" emerge from their long sojourn (seventeen years or so) in the ground they make for a tree or the like, which they ascend. If it is dark or if their eyes are covered they no longer go toward the trees. While the trunks of most trees are considerably darker than the rest of the background, those of some trees (e.g. the sycamore) are lighter. But the Cicadas (which appear to be called "locusts") go toward the latter as well as toward the former. Hence their positive reaction to trees is largely independent of the intensity of the reflected light. They probably perceive the configuration or outline. They almost never climb up on bare buildings. "How the eyes and vision originated in these animals in which they are functional only a few weeks during the seventeen years of their life is an interesting problem." (The origin is surely to be looked for in ancestral forms of different habits.) J. A. T.

δ. Arachnida.

Palpar Organ of Male Spiders.—W. M. Barrows (*Proc. Amer. Soc. Zool.* in *Anat. Record*, 1920, **17**, 351). The palpar organ is a hypertrophied terminal claw or dactylus. Before the last moult of the male spider, the gland which secretes the claw is pulled back toward the centre of the tarsus by the attached muscles, which then degenerate. The mass of gland cells which now forms the foundation of the palpar organ develops an inner tube by the invagination of cells from the tip. In its cramped position the claw twists on itself, developing variously shaped teeth which usually correspond with unmodified teeth on the female claw. The muscles working the claw or palpar organ appear to degenerate and to be replaced by a new set after each moult.

J. A. T.

Injurious Arachnids and Myriopods.—Stanley Hirst (*Species of Arachnida and Myriopoda Injurious to Man, British Museum (Natural History) Publications*, 1917, *Economic Series*, No. 6, 1–60, 26 figs.). An excellent account of spiders, scorpions, ticks, and mites which are directly or indirectly injurious to man. We may note *Holothyrus coccinella*, a mite which secretes an irritant poisonous fluid ; *Cytoleichus hominis*, an acarid found by Castellani in the body of a negro in Uganda ; *Rhizoglyphus parasiticus*, causing "water itch" on the feet of coolies employed in tea-gardens in Assam ; the carnivorous mite *Pediculoides ventricosus*, causing "grain itch" on men handling cotton-seed ; *Nephrophagus sanguinarius*, a mite found dead day after day for a week or more in the urine of a Japanese. There are some other very interesting forms dealt with which are not very generally known. J. A. T.

Behaviour of Sexes in Ixodidæ.—George H. F. Nuttall (*Parasitology*, 1919, **11**, 394–404). The males of *Amblyomma hebræum* anchor immediately when placed in a hungry state upon the host (scrotum of a ram), but females will not do so in the absence of previously anchored males. After the males are fed for some days they show sexual excitement ; without releasing their mouth-parts they seize females that chance to come near. To copulate they must release their mouth-parts. After feeding for two to eight days the females wander and are seized by males. The ventral surfaces are apposed, and the female proceeds to feed, puncturing the skin of the host with her mouth-parts, in close proximity to those of the male. Copulation takes place in due course, the male temporarily removing his mouth-parts from the host for the purpose. A male may copulate with several females. A female may seek two males in succession. Females feed very slowly in the absence of males. They gorge rapidly when fertilized, and, when fully gorged, usually abandon the host without delay.

The males of *Hyalomma ægyptium* anchor immediately when placed on the same host. In the absence of females they remain fixed or change very slightly. They are excited by the close proximity of females. The females do not as a rule change their anchorage from start to finish ; the males seek them out. The sexes of *Rhipi-*

cephalus bursa, when hungry, fix at once on the host. After three to five days the males seek anchored females, a number in succession. As in other species the males remain upon the host after the females drop off, which accounts for the predominance of male ticks on a host.

J. A. T.

Spermatogenesis in Ixodes ricinus.—Erik Nordenskiöld (*Parasitology*, 1920, **12**, 159–66, 1 pl.). The spermatogonium has twenty-eight chromosomes at mitosis; the centrosome appears then as a very conspicuous triangular corpuscle. The spermatocytes of the first and second order are described. The spermatid undergoes intricate metamorphosis, affecting nucleus, cytoplasm, centrosome and mitochondria. The outcome of the changes which the author describes, not very readily summarized, is the formation of an atypical spermatozoon, not easily comparable with the common spermatozoon type. It shows a rod-like, laterally placed nucleus, a conical centrosomal corpuscle united with the nucleus, and a plasma rod with a stainable core. J. A. T.

Fatal Occurrence of a Pentastomid in Man. — Monziols, Collignon, and Jean Roy (*C. R. Soc. Biol.*, 1920, **83**, 28–9). A Senegalese tirailleur died in hospital at Constantinople of severe icteritis, accompanied by cerebral excitement. His liver, of small size, showed in the biliary canaliculi an enormous number of specimens of *Porocephalus armillatus*, marked by four simple hooks and twenty to twenty-two rings. The adult is found in the trachea of large snakes; the larva occurs in monkeys and in man in the deeply situated organs. The epidermis of the specimens is chitinogenous; connective tissue occupies the place of the dermis and the interstices; the walls of the intestine show deep folds; there was no trace of reproductive, respiratory, nervous, or sensory systems; there is a strongly developed muscular system of peripheral fibres (longitudinal and annular) and of deep fibres around the intestine. This is the second instance of this parasite in a Senegalese. J. A. T.

ε. Crustacea.

Fresh-water Harpacticids from Peru.—Th. Delachaux (*Revue Suisse Zool.*, 1918, **26**, 117–27, 1 pl.). Nine species of *Canthocamptus*, including three new ones. The occurrence of *Maraenobiotus naticochensis* is interesting as regards geographical distribution. Attention is directed to a representative of the genus *Godetella*, which is allied to the European *Wolterstorffia* and to the Asiatic *Marshia*, the three genera being primitive types which have undergone a parallel evolution on three continents. The Harpacticids do not live among the plankton of the open water of the lake, but in shallow water among aquatic plants and on stones. J. A. T.

Annulata.

Structure of Sabellids and Serpulids.—W. C. M'Intosh (*Ann. Mag. Nat. Hist.*, 1918, **2**, 1–59, 6 pls.). Sabellid structure is illustrated mainly in reference to *Bispira volutacornis*, attention being directed to

the body-wall, the branchial apparatus (with its chordoid skeleton), the nervous system, the bristles, the blood-vessels, and the thoracic glands or anterior nephridia. Serpulid structure is illustrated mainly in reference to *Pomatoceros triqueter*, with special attention to the body-wall, the peri-intestinal sinus, the thoracic glands, the branchial filaments, the operculum and its development, and the nervous system. The paper is rich in interesting observations ; we cannot do more than indicate its general scope. J. A. T.

Interesting Abnormality in a Serpulid.—Enrique Rioja (*Boll. Soc. Espan. Hist. Nat.*, 1919, **19**, 445–9, 2 figs.). Description of a specimen of *Hydroides norvegica* Gunn. which showed two opercula. The operculum is the result of a transformation of a branchial plume, and the author maintains that the primitive Serpulids had a double operculum. The present day forms show a suppression of one operculum or of both of them, a suppression of the branchlets on the stalk, a diminution of the number of thoracic segments, and an asymmetry associated with spiral coiling. J. A. T.

Nematohelminthes.

Nematode Parasites of Zebra.—Charles L. Boulenger (*Parasitology*, 1920, **12**, 98–107, 7 figs.). Seven species are dealt with—*Strongylus vulgaris*, *Cylindropharynx brevicauda*, *C. longicauda*, *Cylicostomum minutum*, *C. zebræ* sp. n., *C. montgomeryi* sp. n., *Triodontophorus serratus*, and *Craterostomum tenuicauda* g. et sp. n. The first, fourth and seventh are also parasites of domestic equines. The new genus is closely allied to *Triodontophorus* Looss, but differs in the absence of teeth projecting into the mouth-capsule. The mouth is also relatively smaller and the number of elements of the leaf-crowns considerably less than in any known species of *Triodontophorus*. J. A. T.

Trichocephalus in Liver of Rat.—L. Muratet (*C. R. Soc. Biol.*, 1919, **82**, 1383–4). Lesions on the liver of *Mus decumanus* were found to be due to adult specimens of *Trichocephalus*, which occur coiled up in the liver. There were also very abundant ova. Some adult specimens of *Trichocephalus* were also found in the intestine. J. A. T.

Platyhelminthes.

New Species of Oochoristica from Lizards.—H. A. Baylis (*Parasitology*, 1919, **11**, 405–14, 1 pl.). Descriptions of *O. zonuri* sp. n., from *Zonurus tropidosternum*, in Portuguese East Africa, and *O. agamæ* sp. n. in *Agama*. These new forms are contrasted with *O. truncata* from *Agama*, and the genus *Oochoristica* with the genus *Linstowia*. Both genera seem to belong rather to the Dilepinidæ than to the Anoplocephalidæ. J. A. T.

New Species of Anchitrema.—L. Gedoelst (*C. R. Soc. Biol.*, 1919, **82**, 1250–2). Description of *A. latum* sp. n., from the posterior intestine of *Chamæleon dilepis*, differing from the other species of the genus (*A. sanguineum*) mainly in the proportions of the body. J. A. T.

Turbellarians of Mississippi Basin.—Ruth Higley (*Illinois Biol. Monographs*, 1918, **4**, 1–94, 3 pls.). In swiftly flowing streams where a rocky bed furnishes a sheltered place of attachment, Planarians and a few creeping Rhabdocoels find a suitable habitat. For most of the free-swimming species, ponds and temporary puddles are best. They afford a protected retreat and also a feeding-ground in the masses of filamentous algæ, and a source of food in the associated animal communities. The response to the presence or absence of oxygen and carbon dioxide is more precise than that evoked by any other stimulus. The reaction to light varies in different species ; in most instances it is negative, though not definitely so. Response to temperature is general or diffuse, rather than to a localized stimulus, such as the seasonal change in the condition of the water. Since nourishment is obtained mostly from disintegrating protoplasm, the food relationships are very simple, and although nearly defenceless the Turbellarians appear to have few enemies. New species of *Stenostoma*, *Macrostoma*, *Dalyellia*, *Strongylostoma* and *Merostoma* are described, and the precise conditions under which they live are noted. J. A. T.

Intestinal Helminths in Indians in Mesopotamia—C. L. Boulenger (*Parasitology*, 1920, **12**, 95–7). Out of 1,180 individuals examined 1·2 p.c. had *Tænia saginata* ; 2 p.c. *Hymenolepis nana* ; 5·2 p.c. *Ascaris lumbricoides* ; 0·08 p.c. *Oxyuris vermicularis* ; 18·5 p.c. *Anchylostoma* (or *Ancylostoma*) *duodenale* and *Necator americanus* ; 1·2 p.c. *Trichostrongylus* sp. ; 0·5 p.c. *Strongyloides stercoralis* ; and 5 p.c. *Trichuris trichiurus*. Attention is drawn to the fact that *Hymenolepis nana* seems to be the commonest tapeworm met with among Indians.
J. A. T.

Nemertea.

Sex Dimorphism in Nemerteans.—W. R. Coe (*Proc. Amer. Soc. Zool.* in *Anat. Record*, 1920, **17**, 352). Several species of *Nectonemertes* show in the mature males a pair of lateral muscular tentacle-like appendages immediately behind the head. The testes, which are limited to the head region, have a powerful musculature for the forcible ejaculation of the sperms. The females are so different that they have been referred to a separate genus. It is probable that the "tentacles" are both tactile and prehensile. They may serve to hold the females during insemination. J. A. T.

Cœlentera.

Mesenteries in Urticina crassicornis.—James F. Gemmill (*Proc. Zool. Soc.*, 1919, 453–7). The adult *Urticina* is remarkable as having its mesenteries and tentacles apparently arranged in ten-cycled symmetry, and on that account has been placed by various authors among the Paractineæ. It is, however, a Hexactinian, with the arrangement of the mesenteries modified during early growth. The author explains how this comes about. J. A. T.

Evolution in Sea-pens.—SYDNEY J. HICKSON (*Proc. Roy. Soc.*, 1918, **90**, 108–35). 1. Radially symmetrical animals, sedentary or drifting in habit, are far more variable in external form and in the number and arrangement of their organs than are bilaterally symmetrical animals, free and active in their movements. 2. The radially symmetrical Pennatulids are more variable than the bilaterally symmetrical Pennatulids in almost all the important characters upon which the classification is based. This is substantiated in detail. 3. Particularly in the sedentary animals do we find illustrations of plasticity in specific characters. 4. The more primitive Pennatulids are the radially symmetrical forms, and it is probable that between sedentary Alcyonarian ancestors and the Pennatulids we know there intervened an intermediate stage with some powers of muscular movement, such as a floating or drifting colony. J. A. T.

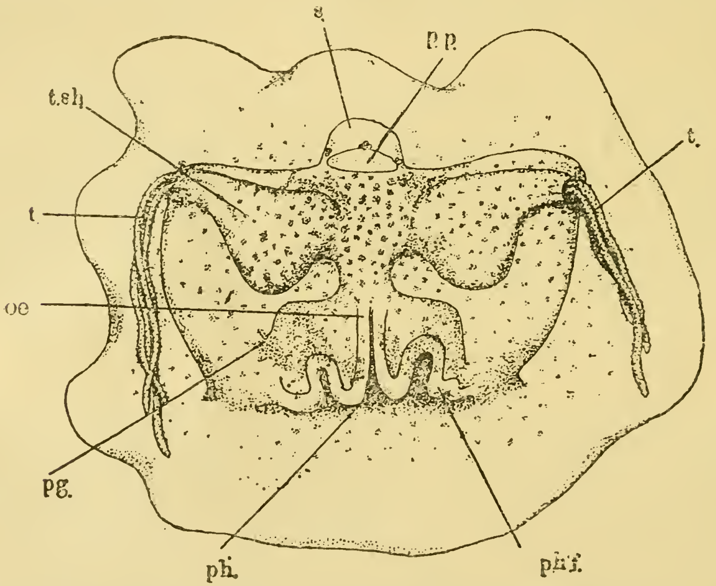
Development of Agaricia fragilis.—J. W. MAVOR (*Proc. Amer. Acad. Arts Sci.*, 1915, **51**, 485–511, 6 pls.). An account of the early stages of this coral common on the shore at Bermuda. A pear-shaped planula fixes itself and becomes flattened. The development of the mesenteries, the mesenterial filaments, and the gastro-vascular cavities is described. The gastro-vascular cavity seems to be formed by a breaking down and splitting of the endoderm. The mesenteries, muscle cells and the cells which will form or have formed the mesenterial filaments are the agents which determine its form. An account is also given of the post-larval development, including the earliest stages of the skeleton. The basal plate and the six primary entosepta are the first structures to be developed. The primary exosepta do not arise simultaneously. Bilateral symmetry is frequently shown in the arrangement of the primary entosepta. There is considerable variability in the development of the septa. J. A. T.

Ciliation of a Leptomedusan.—JAMES F. GEMMILL (*Proc. Zool. Soc.*, 1919, 459–61, 1 fig.). In the gonophore of *Melicertidium octocostatum* (Sars) the radial and ring canals are wide enough to allow the action of the ciliated lining to be studied. The ciliary currents are described in the stomach, the manubrial canal, the radial canal, and the ring canal. There is no ciliation on the exumbrellar surface, but there is much on the sub-umbrellar surface, and the currents are regular, gathering food-particles to the mouth. The tentacles show weak ciliation except on their inner sides near their bases, where they are ciliated more strongly. Their ends are sometimes turned into the mouth. The ciliation of the gastrovascular lining subserves in the first place the mixing and transport of the food, and is also capable of aiding the ingestion of small food particles and the evacuation of the sex-cells through the mouth. J. A. T.

Somatic and Germ-cells in Cœlentera.—GEORGE T. HARGITT (*Proc. Amer. Soc. Zool.* in *Anat. Record*, 1920, **17**, 327). All cells of the Hydrozoan body, except perhaps the stinging-cells and the nerve-cells, are capable of further differentiation in various directions. This includes the power of de-differentiation and of specialization in a new

direction. Therefore, the author says, there cannot be any real distinction between body-cells and germ-cells. (There remains, however, this distinction, that a fertilized ovum can develop into an offspring, which no de-differentiated somatic cell or pair of cells can do.) Specialized cells even in Vertebrates show in varying degrees the power of de-differentiation and new specialization. But there is a time in ontogeny when further specialization of cells involves the loss of capacity of any new differentiation; this is the period at which germ-cells are usually segregated into a distinct tissue. In the higher organisms this may occur early in development; in Hydrozoa it never occurs. J. A. T.

Cœloplana.—TAKU KOMAI (*Annot. Zool. Japon.*, 1920, **9**, 575–84, 5 figs.). Description of a *Cœloplana bocki* sp. n., found abundantly as a commensal of a littoral species of *Dendronephthya*, common near Misaki. It differs from *C. willeyi* and *C. mitsukuri* from the same locality in



Larva of *Cœloplana bocki*, adhering to the substratum by the thin expanded sole. The main body is laid back and seen on the transverse plane. × 170.

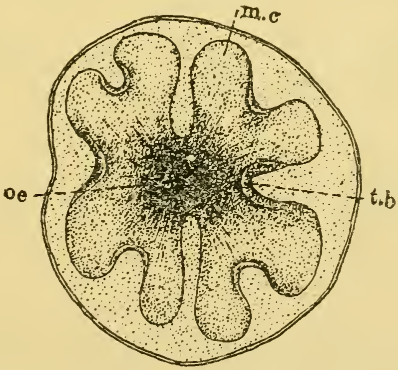
ph.', inner part of pharynx; *pg.*, pigment spots; *œ.*, œsophagus; *t.*, tentacle; *t.sh.*, tentacle sheath; *s.*, aboral sense-organ; *pp.*, polar plates; *ph.f.*, pharyngeal folds

being much smaller, in peculiarities of coloration, and in having two to five lobe-like processes around the periphery of the polar plates. It is hermaphrodite, and some specimens overlay clusters of developing eggs in direct contact with the ventral surface. The segmentation and gastrulation are as in other Ctenophores, and there is a Cydippid larva. There can be no doubt that the genus is derived from a Cydippid stock

by a loss of certain characters and a concomitant acquisition of new features adapted to the change from free-swimming to creeping life. There is evidence that the entire creeping surface of *Cœloplana* is derived from a turning out of a large part of the inner pharyngeal surface of ordinary Cydippids. It seems that the flatness of the body in this aberrant form is largely due to this, and not merely to a reduction of the vertical axis of the body. J. A. T.

Ciliary Action in Pleurobrachia pileus.—JAMES F. GEMMILL (*Proc. Zool. Soc.*, 1918, 263–5, 2 figs.). In the internal cavities of this Ctenophore there is very orderly "circulation" maintained by ciliary action, and detected by the motion of particles suspended in the contained fluid—e.g. small oil globules, alimentary particles and débris. There are aboralward and oralward currents in the stomodæum, and there is a more complex circulation in the canal system. J. A. T.

Gastrodes parasiticum Korotneff.—TAKU KOMAI (*Annot. Zool. Japon.*, 1920, **9**, 585–90). An account of this imperfectly known and remarkable parasitic Cœlenterate, found embedded in the test of Salpa. Korotneff, the discoverer of the animal, referred it at first to the

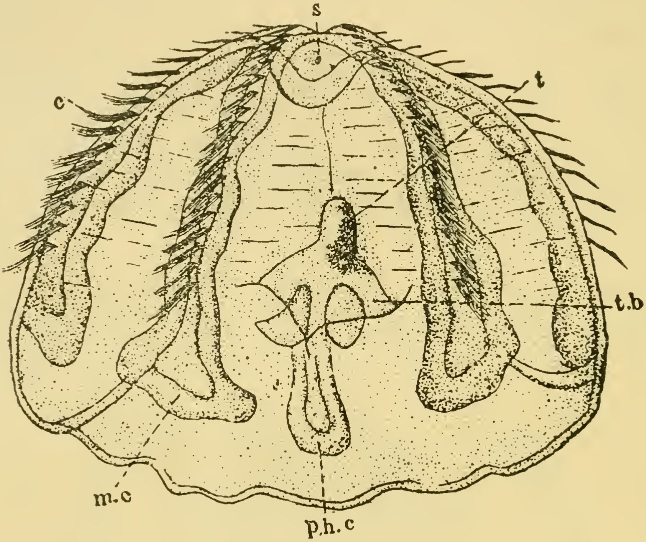


Dorsal view of an early stage of *Gastrodes parasiticum* Korotneff. × 90.

œ., œsophagus; *m.c.*, meridional canal; *t.b.*, tentacle basis.

Narcomedusæ and afterwards to the Actiniæ. Heider regarded it as a degenerate Ctenophore, and Ctenophore it is. The colourless disc-like body is more or less convex on the dorsal side, and measures 0·5–3 mm. in diameter. The gastrovascular system is represented by a connected pair of cavities, each laterally divided into four peripheral pouches; the œsophagus is not laterally compressed; the tentacle apparatus is indicated by mere thickenings of the epidermis, and the aboral sense-organ by a shallow depression containing as yet no otolithic mass. From such simple stages there is a gradation to forms with eight rows of comb-plates, an aboral sense-organ, and a tentacle apparatus. It is likely that

the animal becomes free. It is probably referable to the Platyctenea. This is indicated by the covering of the ventral surface with ciliated epithelium and the profuse foldings in the central region of that surface. The ventral surface may have arisen, as in *Cœloplana*, by a turning out



Advanced stage of *Gastrodes parasiticum* Korotneff, which has changed from a more flattened to a hemispherical shape on liberation from the host. × 50.

c., comb-plates; *s.*, aboral sense-organ; *t.b.*, tentacle basis; *m.c.*, meridional canal; *ph.c.*, pharyngeal canal; *t.*, tentacle.

of the pharynx. Moreover the œsophagus is well differentiated, the meridional canal exhibits signs—though slight—of branching, and the infundibular canal is obliterated. J. A. T.

Protozoa.

Influence of Environment on Arcella.—Robert W. Hegner (*Journ. Exper. Zool.*, 1919, **29**, 427–41, 7 figs.). When specimens of *Arcella dentata* are underfed, the interval between successive divisions increases from an average of 2·5 days to about 4; the shell decreases in diameter on the average 2·68 units of 4·3 μ each; the spine number slightly decreases. The offspring are normal when given abundant food. In a medium containing 1 drop of sodium silicate to 100 cc. of water *A. dentata* grows and reproduces; the fission rate decreases as above; the size of the progeny produced in the solution is reduced; the spines disappear; the colour, which becomes brown in a normal medium, remains a pale greenish yellow. Specimens reared in this

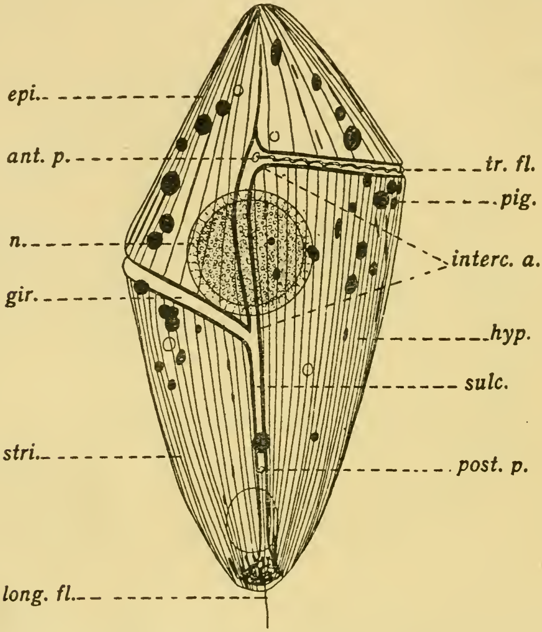
solution and then returned to a normal medium regain the fission rate, size, spine length, and colour characteristic of the race. Specimens grow and reproduce in a medium with 0·25 to 1 p.c. of alcohol, but the alcohol is injurious, as indicated by the retarded fission rate and irregularities in the shells of the offspring. Lowering the temperature seems to lead to reduction of the length of the spines. Wild specimens of *A. polypora* with a bent oval shell with an oval mouth gave rise in laboratory conditions to offspring with a flat circular shell and a circular mouth opening. It appears, then, that modifications induced by environmental peculiarities persist only so long as the modifying factors are operative. No heritable diversities were observed that were due to the changed conditions. J. A. T.

Intestinal Protozoa in Members of Egyptian Expeditionary Force.—F. W. O'Connor (*Parasitology*, 1919, **11**, 239–55, 1 pl., 3 figs.). Report dealing with *Entamœba histolytica*, *E. coli*, *Trichomonas hominis*, *Lamblia intestinalis*, "*Entamœba*" *nana*, *Tricercomonas* and *Isospora hominis*. J. A. T.

Race of Oxytricha without a Micronucleus.—J. A. Dawson (*Journ. Exper. Zool.*, 1919, **29**, 473–513, 2 pls.). A pedigreed culture of *Oxytricha hymenostoma* was kept up for 289 generations (from July 10, 1917, to April 30, 1918), and no micronucleus was seen. Nor was there any true conjugation or syngamy. Individuals fused in pairs in a manner similar to that of conjugating individuals, and remained fused till death occurred, or else separated and went on multiplying. Cannibalism was frequent and digestion rapid. Cannibalism has the effect of raising the division rate somewhat for a short time. The amicronucleate condition seems to preclude the occurrence of conjugation, autogamy, and endomixis; yet without these the race flourishes in favourable environmental conditions. J. A. T.

Structure of Noctiluca.—Charles A. Kofoid (*Univ. California Publications, Zoology*, 1920, **19**, 317–34, 1 pl., 2 figs.). A new interpretation is offered, that *Noctiluca* is a dinoflagellate highly modified through distention by hydrostatic vacuoles. It retains the dinoflagellate sulcus, modified anteriorly into the apical trough and the recessed oral pouch and cytostome. Of the girdle only the proximal part persists; it has been hitherto overlooked. It is a shallow trough at the left of the sulcus and at right angles to it. It is best seen in small individuals. With the degeneration of the girdle has gone the reduction of the transverse flagellum to the prehensile tooth which lies at the proximal end of the girdle at the left of the base of the longitudinal flagellum. This organ exhibits structural undulations and spasmodic and rhythmical contractions. The longitudinal flagellum is reduced and lies within the oral pouch. It is the distention with hydrostatic vacuoles, with flotation replacing active locomotion, which has led to the degeneration of the flagella and their reduction in size, and to the almost complete disappearance of the girdle. The posterior tentacle is the homologue of the

tentacle of *Pavillardia* and *Erythropsis*, and is not a modified flagellum. The order Cystoflagellata is not required for *Noctiluca*; it may remain in the meantime for *Leptodiscus* and *Craspedotella*. The structure of



A typical dinoflagellate, *Gyrodinium corallinum* g. et sp. n. (Kofoid and Swezy MSS.). × 500.

Ant.p., anterior pore; *epi.*, epicone; *gir.*, girdle; *hyp.*, hypocone; *interc.a.*, inter-cingular area; *long.fl.*, longitudinal flagellum; *n.*, nucleus; *pig.*, pigment; *post.p.*, posterior pore; *pus.*, pustule; *sulc.*, sulcus; *tr.fl.*, transverse flagellum.

Noctiluca should be compared with that of a typical dinoflagellate (see figure), with sulcus, girdle, and flagella, but it has no theca or cuirass.

J. A. T.

Renewal of Vitality through Conjugation.—Gary N. Calkins (*Journ. Exper. Zool.*, 1919, **29**, 191–56, 1 chart, 1 fig.). In the hypotrichous ciliate *Uroleptus mobilis* the processes of metabolism are not capable of unlimited activity. The limits vary from 268 to 349 generations after conjugation or encystment. There is an optimum during the first three months after conjugation, and then a progressive and cumulative weakening of metabolic vigour, leading to death. Conjugation, however, changes the protoplasm from metabolic weakness to optimum vigour. There is a limit to the extent to which the protoplasm can be rejuvenated. It seems as if the protoplasm could hold only a certain charge, so to speak, or potential of metabolic vigour, as a

result of conjugation. This optimum is subject to change by environmental conditions, being increased, for example, by heat. It also appears that rejuvenescence may follow encystment and parthenogenesis when no nuclear interchange has occurred. In some cases the rejuvenating effect of parthenogenesis was even greater than that of conjugation. Parthenogenesis through encystment seems to be an attribute of high vitality, and the ability to encyst is apparently lost at an early date. The condition of physiological depression is accompanied by structural changes, which are described in detail. In conjugation the most significant phenomenon is the granular disintegration of the old macronuclei and the absorption of relatively large quantities of nuclear substance in the cytoplasm. The same is true of encystment and in division—there is re-organization of the cytoplasm.

J. A. T.

Periodicity in Photic Responses of a Euglenoid.—S. O. Mast (*Proc. Amer. Soc. Zool.* in *Anat. Record*, 1920, **17**, 345). In some organisms—eg. *Convoluta*—changes of movement continue for some time in the absence of the environmental conditions to which they were formerly related (the tides in the case mentioned). Like many of the Euglenoids, *Septocinclis texta* responds very definitely to light. If kept in total darkness and tested from time to time in an illumination of proper intensity, it is positive from early morning to about 1 p.m. It then becomes negative, and remains so till 8 or 9 p.m., when it becomes positive again until the following afternoon. Thus in the absence of light, for at least three days, there appears to be in its physiological processes a periodicity which is normally associated with alternation between day and night, and determines whether its orientation to light is positive or negative. J. A. T.

Adaptation to Light in Euglena variabilis.—S. O. Mast (*Proc. Amer. Soc. Zool.* in *Anat. Record*, 1920, **17**, 346). *Euglena* becomes rapidly adapted to any given illumination, and if adapted to low illumination or darkness it tends to be negative in strong and positive in weak light, and to aggregate in moderate illumination. If adapted to high illumination, it tends to be positive in strong and negative in weak light, and to aggregate in very high and very low illumination. J. A. T.

Trichomonas of Guinea-Pig.—Edouard Chatton (*C. R. Soc. Biol.*, 1920, **83**, 69–72). An account of attempts to secure a pure culture of a species of *Trichomonas* which is often very abundant in the cæcum of the guinea-pig. It lives well in ordinary bouillon to which blood is added, but it was not found practicable to get rid of four kinds of associated bacteria. The flagella are markedly alkalinophilous. In the culture the recurrent flagellum of *Trichomonas* separates from the body, suppressing the undulating membrane. When inoculated into the peritoneum of the guinea-pig there is a reappearance of the undulating membrane. In different media there are different surface-tension conditions which may influence the structure; there may also be an influence from specific substances. The transformation shows how close the relationship is between *Trichomonas* and *Trichomastix*. J. A. T.

Parasites in Chiton and Patella.—PAUL DEBAISIEUX (*C. R. Soc. Biol.*, 1919, **82**, 1400–2). In Chitons there are at least three distinct parasitic Protozoa. In *Acanthochites fascicularis* the liver and the epithelium of its ducts contain large numbers of *Pseudoklossia chitonis* sp. n., while the salivary glands abound in stages of one of the Eimeridea. In many organs of *Craspidochilus cinereus* there is *Haplosporidium chitonis* (= *Minchinia chitonis*). In *Patella vulgaris* there is a new form, *Pseudoklossia patella* sp. n. J. A. T.

New Species of Haplosporidium.—PAUL DEBAISIEUX (*C. R. Soc. Biol.*, 1919, **82**, 1399–1400). In specimens of the long Nemertean *Lineus marinus* there were very numerous spores of a new species of *Haplosporidium* (*H. nemertis*). They occurred especially in the connective tissue between the gut and the longitudinal muscles, forming an almost continuous layer. The youngest stages are subspherical and binucleate masses—small plasmodia. These grow and show a multiplication of nuclei, three to five divisions being observed. The nuclei increase in size and undergo two more successive divisions ; the multinucleate plasmodium resolves itself into uninucleate sporoblasts, which are transformed into spores. Some large plasmodia resolve themselves into the binucleate forms mentioned above, which spread the infection in the host. J. A. T.

Nutrition of the Protozoa. The Growth of Paramœcia in Sterile Culture Medium.—R. A. PETERS (*Proc. Phys. Soc.*, 1920, **53**, 108–9). As a preliminary step to the study of the metabolism and reactions of Paramœcia in solutions of known chemical composition, pure cultures free from bacteria are needed. Cultures of a race of Paramœcia about 50 μ in length, isolated from a single individual, have been obtained in the following medium :—

	Per cent.
Sodium chloride	0·06
Potassium chloride	0·0014
Calcium chloride	0·0012
Basic sodium phosphate (NaHPO)	0·0001
Acid potassium phosphate (KHPO)	0·0001
Magnesium sulphate	0·001
Sodium bicarbonate	0·002
Phenol red	Trace
Glucose	0·03
Histidine	0·01
Arginine	0·01
Leucine	0·01
Ammonium lactate	0·003
Ferric chloride	Trace
Potassium iodide	Trace
Manganous chloride	Trace

The above substances are made up with glass-distilled water. The constituents are autoclaved separately. The final mixture is sterilized by heating to 80°C. on three successive days. The reaction is adjusted to PH = 7·4 with NaOH N/100. The organisms were cultivated in sterile media in depression slides, experiment showing the most suitable concentration for division. After a number of individuals had been

obtained, sub-cultures in test-tubes were made with all sterile precautions, and when a good tube-culture had been obtained it was used for culture purposes as required. (Temperature, 15–20° C.)

No bacterial or other adventitious growth was obtained by sowing from these successful cultures into (1) nutrient broth, (2) nutrient agar, (3) glucose agar, and (4) litmus milk, at room temperature or at 36°C.; nor on the special medium itself stiffened with agar; although peculiar rod-shaped bodies (10 μ long by 2 μ broad) were detected in growing cultures with a $\frac{1}{12}$th-in. oil-immersion lens. Experiments with the special medium showed that when single amino acids were supplied, histidine, arginine, and leucine gave more rapid growth than tryptophane; also that galactose and fructose, but not maltose, could be substituted for glucose. J. E.

BOTANY.

GENERAL,

Including the Anatomy and Physiology of Seed Plants.

Cytology,

Including Cell-Contents.

Mitochondrial Origin of the Plastids.—A. Guilliermond (*Ann. Sci. Nat.* (*Bot.*), 1919, ser. x., **1**, 225–47, 5 pls., 10 figs.). A paper dealing with Mottier's recent work in connexion with the origin of the mitochondrias (*Ann. of Bot.*, 1918, **32**). The latter writer claims to have proved that plastids and mitochondrias are two different and distinct constitutional elements of plant-cells. The present work is intended to show that plastids are specialized forms of mitochondrias. It is pointed out that in animal cells the mitochondrias have been proved to perform the same functions as the plastids of plant-cells—i.e. they elaborate different nutritive products and pigments. The writer also claims to have proved conclusively that the yellow pigment of the tulip is formed by the chondriocontes; also, that the epidermal cells of the leaf of *Iris germanica* contain amyloplasts which are identical in every respect with the chondriocontes. It is admitted that mitochondrias and plastids may be formations of the same nature and significance, but evolving separately and having distinct elaborative functions—i.e. there are varieties of mitochondrias each specialized for its own particular function. It appears preferable to regard both mitochondrias and plastids as different forms evolved from a common origin, and the writer claims that investigations made by himself and other botanists fully confirm the work done by animal cytologists, and show that while some of the mitochondrias retain their primitive form, others develop into chondrioplasts in the animal cell and plastids in the plant cell. S. G.

Structure and Development.

Vegetative.

Exudation of Water by Colocasia.—M. G. Flood (*Sci. Proc. Roy. Soc. Dublin*, 1919, **15**, 505–12, 2 pls., 1 fig.). The writer has studied the leaves of *Colocasia antiquorum* in order to locate the gland or tissue responsible for effecting the exudation or the filtration of the water. Rapid transfer of water through the petiole and blade is indicated by the lacunæ in the petiole, canals in the leaf, and spaces and perforations in the mesophyll. These features, however, do "not support the hypothesis that the water is secreted by cells in the tissues of the apex, or is even filtered there." It was not possible to demonstrate by histological methods the presence of continuous membranes under the pores in the

depressions of the leaves, but physical methods were devised which showed that the exuded water was not a secretion from a gland in the leaf-tip. All the experiments prove that there is no special tissue which can be regarded as a gland; neither is there any membrane between the water-channels and the depressions for filtering water. All the structures indicate that "cells lower down in the plant are responsible for the secretion or filtration of water, and there seems no evidence for the existence of special cells for this function outside the root." S. G.

Reproductive.

Reproductive Organs and Phylogeny of the Amentales.—P. Vuillemin (*Ann. Sci. Nat.* (*Bot.*), 1919, ser. x., 1, 139–200, 3 figs.). An account of the reproductive organs of the Amentales, with special reference to their bearing upon the phylogeny of this group. In describing these organs the author employs the term "amphigonelle," and points out that while a true inflorescence has numerous monocentric axes, the amphigonelle has a single polycentric axis. Like the pedicel, the polycentric axis arises in the axil of a leaf, which may be unmodified, or bract-like, or elongated into a leafy stem; in the first case the axillary shoot is entirely reproductive, and in the other cases it is partly vegetative and partly reproductive. The amphigonelle may resemble a capitulum, a spike, or a glomerulus. In the Cupuliferæ the axis is oligocentric, being sometimes a true stem with typical vegetative leaves, as in *Quercus* and *Fagus*, in other cases functioning as a peduncle; while the reproductive organs resemble an inflorescence in which a vegetative shoot is subordinated to the reproductive shoots. The amphigonelles enclose sexual organs—unisexual in the lower Amentales, bisexual in the higher types. The primitive male organ is dichotomous, with two filaments and two unilocular anthers, but the dichotomy is gradually suppressed from below upwards, until finally there is a single filament bearing a bilocular anther. The female organs are represented by the nucellus, placentas, and stigmas. No true carpels have been found in the Amentales; the ovary is of the nature of a leafy emergence surrounding the female organs, the partitions corresponding to the outgrowths of the leaf (e.g. the Juglandaceæ) or to prolongations of the placenta (e.g. the Casuarineæ and Betulaceæ).

The appendages of the amphigonelle are sepals and bracteoles. In the lower groups the sepals are often attached to the stamens or stigmas, while in the higher groups these appendages come into close union with the organs, and become the ovary composed of carpels. In certain female amphigonelles some or all of the bracteoles form a primitive cupule; the latter is well differentiated in the Cupuliferæ, but in the lower families of the Myricaceæ and Juglandaceæ it is very rudimentary. In tracing the phylogeny of the Amentales it has not been possible to fix any direct line of descent, but taking into account numerous indications of affinity, we have a system of short branches arising one from another at different angles of divergence. Through the Casuarineæ the Amentales are derived directly from the Protosperms, the common source of the Gymnosperms and Angiosperms, themselves derived from

the Mesophytes, which also give rise to the Muscineæ. The Amentales show traces of their relationship to the Muscineæ, and in some respects resemble the Gymnosperms, more especially the Gnetaceæ. The Cupuliferæ, although higher than the Casuarineæ, have diverged less from the direct line than the Myricineæ; the other families—Salicineæ, Piperineæ, Chloranthineæ, and Juglandaceæ—start at different levels from the branch which terminates in the Myricaceæ. S. G.

CRYPTOGAMS.

Pteridophyta.

Contribution to our Knowledge of the Vascular System of the Genus Equisetum.—Kate Barratt (*Ann. of Bot.*, 1920, **34**, 201–35, 2 pls. and figs.). An investigation of the anatomy of the sporeling and the development of the vascular system. 1. The sporeling of *E. arvense* is protostelic at its base, siphonostelic where the vascular supply of the secondary axis is attached, and protostelic again for a short distance below where the first whorl of leaves is attached. 2. The basal regions of the succeeding axes of the young plant possess a compact closed siphonostele composed of short reticulate tracheids. There is thus formed a sympodial vascular tube in which five or more axes may be concerned. 3. The secondary axis arises endogenously from the primary axis below the level of the first leaf-whorl. 4. The vascular structure of an anomalous tuber is described, in which carinal canals are formed in connexion with the protoxylem, and these in the middle region of the tuber are enveloped by separate endodermis. 5. A young sporeling of *E. limosum* is described showing a forked primary axis. The arrangement of the vascular system indicates that it has almost certainly arisen by a dichotomy. 6. Secondary thickening of the nodes of *E. arvense* and *E. maximum* was studied in the light of the development of the nodal tracheids; and the conclusion was arrived at that the apparent increase in elements, which has been attributed to secondary thickening, is due to the enlargement and displacement of developing tracheids. 7. The vascular structure of the cones of *E. arvense*, *E. maximum*, *E. palustre*, *E. limosum*, and *E. sylvaticum* is described. The endogenous protoxylem strands are shown to form complete and continuous systems, uninterrupted by nodal tracheids, as is invariably the case in vegetative shoots. The metaxylem develops later, and varies in amount and distribution in the different species. *E. arvense* shows the greatest amount, and *E. limosum* and *E. sylvaticum* the least. It is concluded that the gaps in the metaxylem siphonostele cannot be described as leaf-gaps, bearing no relation to the sporangiophore traces, but may be related to the mechanical efficiency of the cone. It is also concluded that the vascular structure of the cone indicates that the sporangiophores are not the morphological equivalent of leaves, but are organs *sui generis*, and the axis of the cone is undifferentiated into node and internodes. 8. The general vascular system of the plant is discussed, and it is concluded that the general plan of development proceeds

from a simple protostele which opens out into a siphonostele. This shows a considerable reduction in the cone by the development of large parenchymatous meshes or longitudinal tracks, and still further reduction in the internodes of vegetative shoots. A. GEPP.

Third Contribution to our Knowledge of the Anatomy of the Cone and Fertile Stem of Equisetum.—ISABEL M. P. BROWNE (*Ann. of Bot.*, 1920, **34**, 237–63, 2 pls. and figs.). An account of the fertile region in *E. hyemale* and *E. giganteum*. 1. The following series shows the species arranged according to the gradual reduction of the vascular system in the cone: (*a*) *E. arvense*, (*b*) *E. hyemale*, (*c*) *E. palustre*, (*d*) *E. giganteum*, (*e*) *E. maximum*, (*f*) *E. limosum*. In (*a*), relatively to its size, the vascular system is by far the best developed, and in (*e*) and (*f*) by far the most reduced; in (*b*) (*c*) (*d*) the reduction of xylem has proceeded in somewhat different ways, but on the whole to much the same degree. 2. The reduction of the xylem of the cone is manifested in *E. hyemale* and *E. giganteum*, as in the other species studied, by the persistence of parenchymatous meshes, arising vertically above traces that have departed, upwards into more than one internode, and by their extension laterally above traces given off from at or near the edge of a strand. Both phenomena may be considered to be due to poor development of axial xylem at the nodes of the cone. 3. Specially characteristic of *E. hyemale*, and showing relatively good development of the vascular system, are the following points: (*a*) the closure of parenchymatous meshes by the formation of additional tracheids at the node rather than by the oblique course of the tracheids of the branches of a strand above the departure of a trace; (*b*) the relatively large number of parenchymatous meshes and the high proportion among these of meshes of the first and second orders. 4. In *E. giganteum* a relatively high development of the xylem of the cone is shown: (*a*) by the slightly greater radial extent of the xylem in this species; (*b*) by the not infrequent development of wide internodal tracts of xylem, involving the absence of parenchymatous meshes over median traces; (*c*) by the fact that closure of parenchymatous meshes more often involves the formation of additional tracheids than the oblique course, and ultimate fusion of groups of tracheids lying on either side of the mesh; and (*d*) by the fact that this fusion of strands, owing to the formation of additional tracheids, not infrequently occurs considerably below the node. 5. Both in *E. hyemale* and *E. giganteum* the sporangiophores of successive whorls alternate with considerable regularity. But the traces at their insertion on the axial stele do not alternate regularly with those of the whorls above and below. In both species regular superposition occurs when parenchymatous meshes persist unnarrowed on either side of a trace-bearing strand through two or more nodes. This superposition, being due to poor development of axial xylem at the nodes, is less common than in *E. maximum* or in *E. limosum*. Within the species the specimens with less well-developed xylem show more numerous examples of superposition of traces. 6. The traces of the sporangiophores of *E. giganteum* are the most massive yet described for the genus. 7. The traces of the lowest whorls of the

cone of *E. hyemale* tend, even when young, to be deflected slightly downwards while passing outwards through the cortex. 8. In *E. hyemale* the axis is narrower at the base than in the middle or slightly above the middle of the cone ; but the internodal axial strands and members in a whorl are markedly more numerous at the base of the cone. Consequently the vascular bundles are much closer to one another in the annular region than in the wider parts of the axis of the cone. This probably partly accounts for the relatively high number of meshes closed at or near the level of insertion of the annulus. Above the latter numerous fresh meshes arise. 9. In *E. giganteum* the annulus is normally sporangiferous, the sporangia being attached by their upper ends to the free incurved edge of the annulus. A vascular strand runs to the point of insertion of each sporangium. The number of the latter bears no constant relation to that of the strands in the axis or the lobes of the annulus. The annular bundles may remain free from or be connected with the axial stele ; they may branch or remain unbranched. 10. *E. giganteum* differs from the other species studied in that no fresh parenchymatous meshes arise above the annulus. The nodal nature of the axis at the level of the insertion of the latter is, however, supported by the analogy with other species, and by the closure of some parenchymatous meshes in this region. 11. The sporangiferous annulus is regarded as derivative in the genus *Equisetum*, and the reasons for this view are briefly examined. 12. In *E. giganteum* the uppermost vegetative node of the fertile branch shows no persistent diaphragm. A. G.

Phylogenetic Considerations on the Internodal Vascular Strands of Equisetum.—ISABEL M. P. BROWNE (*New Phytologist*, 1920, **19**, 11–25, 7 figs.). A discussion of the structure and nature of these strands, the treatment of which is somewhat meagre in the text-books. The question of which is the most primitive type of internodal bundle in *Equisetum* is considered, as also the direction of lignification of the lateral groups of metaxylem. A. G.

Studies in the New Zealand Species of the Genus Lycopodium: Part I.—J. E. HOLLOWAY (*Trans. Proc. New Zealand Inst.*, 1916, **48**, 253–303, 2 pls. and figs.). A detailed account of the New Zealand species, including the occurrence and habit of the mature plant, the occurrence and structure of the prothallus, the nature of the dependence of the young plant upon the prothallus, and the vascular anatomy of both the "seedling" and the full-grown plant. The results are as follows :—Prothalli of seven species are described and are grouped under four types : (1) *Phlegmaria* (*L. Billardieri*) ; (2) *Cernua* (*L. laterale*, *L. ramulosum*) ; (3) *Clavata* (*L. volubile*, *L. fastigiatum*) ; (4) *Complanata* (*L. scariosum*) ; and it is presumed that *L. densum* will be added to one or other of the latter two types. A large foot is characteristic of the embryo in *L. volubile*, *L. densum*, *L. fastigiatum*, *L. scariosum*, while in case of *L. laterale* and *L. ramulosum* there is an exceptionally large and long-lived protocorm. This latter is presumed to be merely a physiological adaptation. As to the vascular cylinder a stellate or radial configuration is characteristic in *L. Selago*, *L. Billardieri*, and *L. varium* ;

a mixed type in *L. cernuum*, *L. laterale*, and *L. Drummondii*; and a parallel type in *L. volubile*, *L. densum*, *L. fastigiatum*, and *L. scariosum*. The radial or stellate type is regarded as being the more primitive.

The author discusses the taxonomic sections of *Lycopodium* adopted by Pritzel and finds them to agree, in the main, with the chief characters of both the sexual and the asexual generations of the various species. He also summarizes the views of writers as to whether these main sections are more or less nearly inter-related or are widely separated, and finds that the inter-relationship view is more widely held than is the other. And from his own studies he believes that the *Selago* section contains the most primitive members of the genus, and that from it have been derived the *Phlegmaria* and *Clavata* sections, but that the exact relation of the *Cernua* and *Inundata* sections is difficult to gauge. The type of prothallus in *L. cernuum* is commonly regarded as primitive for the genus; but other characters of the species seem to be highly specialized. Hence *Cernua* and *Inundata* are best regarded as groups parallel with *Selago*. A. G.

Studies in the New Zealand Species of the Genus Lycopodium: Part II. Methods of Vegetative Reproduction.—J. E. Holloway (*Trans. Proc. New Zealand Inst.*, 1917, **49**, 80–93, 2 pls. and figs.). A description of the methods of vegetative propagation observed in New Zealand species. These are—(1) Vegetative propagation of the prothallus; (2) isolation of portions of lateral branches or of the main axes of the plagiotropic species; (3) bulbils on adult plants; (4) root-tubercles; (5) gemmæ produced from cortical cells of old roots; (6) bulbils on detached leaves; (7) vegetative reproduction of the protocormous rhizome. In no case in *L. cernuum*, *L. laterale* and *L. ramulosum* has the author ever noticed fungal hyphæ in the cells of the protocorm. A store-tuber comparable to the protocorm is sometimes found on detached leaves of *L. ramulosum* in relation to an adventitious bud; also the adventitious plantlets derived from cortical cells of roots begin as tubers, as also do those budded off from the protocormous rhizome of *L. ramulosum*; and these cases are comparable with the annually produced tuber in *Phylloglossum*, which initiates a new plant. A. G.

Studies in the New Zealand Species of the Genus Lycopodium: Part III. The Plasticity of the Species.—J. E. Holloway (*Trans. Proc. New Zealand Inst.*, 1919, **51**, 161–216, 6 pls. and figs.). An account of the variations observed by the author in the main characters of the New Zealand species of *Lycopodium*. The five main characters studied are—(1) Habit of growth and external form; (2) stem-anatomy; (3) nature of fertile region; (4) form and structure of prothallus; (5) form of young plantlet. From these five points of view the variations of the eleven known species are investigated in detail at some length under their sectional headings—(1) *Selago* and *Phlegmaria*; (2) *Inundata* and *Cernua*; (3) *Clavata*; and it is shown that the species are in a condition of considerable plasticity. The evidence obtained is further digested in a lengthy summary. A. G.

Prothallus and Young Plant of Tmesipteris.—J. E. Holloway (*Trans. Proc. New Zealand Inst.*, 1918, **50**, 1–44, 3 pls. and figs.). The subject is treated in chapters, as follows :—Occurrence and habit; general form and structure of the prothallus; the distribution of the sexual organs; development of the sexual organs; the development of the embryo; development of the young plant; development of the vascular anatomy; comparative remarks. The author compares his results with those of A. A. Lawson, and finds himself in agreement in many particulars—as to the subterranean saprophytic prothallus, its brown colour and covering of rhizoids; its cylindric form, and its branching; its endophytic fungus; the distribution of the antheridia and archegonia scattered all over the surface; the structure of the mature sexual organs; the embryo borne on a prothallial protuberance; the peculiar lobular development of the epibasal portion of the embryo. But he finds Lawson's prothalli to be much smaller and tender, with twisted rhizoids, with a different distribution of the endophytic fungus, and with the prothallium lobes pointed. The explanation may be that under *T. tannensis* two species are included, Holloway's material being of the form known as *T. lanceolata*, which differs from this type in both habit and histological details. The author points out how the prothallus of *Tmesipteris* differs from those of Ophioglossaceæ and Lycopodiaceæ; and cites the evidence for the near affinity of *Tmesipteris* and *Psilotum*, and for the connexion of these Psilotaceæ with certain of the fossil Sphenophyllales. He discusses the question as to whether the Psilotaceæ are to be regarded as primitive, or as the result of reduction, or as being recent adaptations; he draws an analogy from the Equisetaceæ and the Lycopodiaceæ, and gives a résumé of what is known of *Rhynia Gwynne-Vaughani*, referred by Kidston and Lang to a new class, Psilophytales; and he concludes that the Psilotaceæ are to be regarded as of a primitive character. In a postscript he points out how his researches correspond more closely with Lawson's second account of *Tmesipteris* than with the first. A. G.

Cantheliophorus, Bassler : New Records of Sigillariostrobus (Mazocarpon).—M. Benson (*Ann. of Bot.*, 1920, **34**, 135–7). Some criticisms of Bassler's recent paper on a Sporangiophoric Lepidophyte from the Carboniferous—namely, *Cantheliophorus.* The view is put forward that the material may be referred to *Sigillariostrobus* on the ground of—(1) The general occurrence free from the axis of the cone; (2) the form of the sporange and the bract; (3) the occurrence of lateral lines, some of which suggest the vascular pedicel and some the "lateral lamella" of *Mazocarpon*; (4) the indication of a bulky sporange wall and the relatively small spore-bearing region. Most of Bassler's specimens are to be welcomed as further examples of Sigillarian microsporophylls, of which previously only one incrustation record was known. A. G.

Pit-closing Membrane in Ophioglossaceæ.—Gertrude Wright (*Bot. Gaz.*, 1920, **69**, 237–47, 2 pls. and figs.). An account of some investigations of *Helminthostachys zeylanica*, *Ophioglossum vulgatum* and *Botrychium obliquum*, with a view to determining the presence or absence

of a pit-closing membrane—a matter of dispute in all vascular Cryptogams. Halft and Bancroft have proved the presence of the membrane, but did not study the Ophioglossaceæ. This omission the present author makes good by figures and description. Only with the greatest difficulty could the membrane be demonstrated clearly in *Helminthostachys*, but more easily in *Ophioglossum* and *Botrychium*. The methods of staining are explained; and the torus or thickening of the membrane is discussed.
A. G.

Some Impressions of Pteris aquilina L. in the Tufa of the Villa Torlonia at Frascati.—R. Meli (*Atti Pontif. Accad. Romana dei Nuovi Lincei.*, 1919, **71**, 49–64). A résumé of papers previously published upon this subject, with criticisms and additional information. The living ferns were buried in position by a fall of volcanic dust and cinders, thus differing from other instances, as from the Valley of the Tiber and of the Sacco, and from Onano in the Vulsinî, where the impressions, mingled with those of other plants, are mostly disposed horizontally in the tufa. A. G.

Norfolk Island Species of Pteris.—R. M. Laing (*Trans. Proc. New Zealand Inst.*, 1916, **48**, 229–37, figs.). A revision based on good and abundant material, and an attempt to identify with certainty Endlicher's species, described in 1833. The results are as follows:—A. Veins forked—(1) *Pteridium esculentum* Cockayne (*Pteris esculenta* Forst. f.); (2) *Pteris tremula* R. Br., *P. Baueriana* Dies.); (3) *P. Kingiana* Endl.; (4) *P. biaurita* L. var. *quadriaurita* Retz. (? *P. Trattinickiana* Endl.). B. Veins anastomosing—(5) *P. comans* Forst. f. (? *P. Zahlbruckneriana* Endl.); (6) *P. Brunoniana* Endl.; (7) *Histiopteris* (*Pteris*) *incisa* (Thunb.) J. Sm. The author contends that *P. Brunoniana* is a good species. The text-figures are clear and accurate. A. G.

Bryophyta.

Spermatogenesis in Blasia.—Lester W. Sharp (*Bot. Gaz.*, 1920, **69**, 258–68, 1 pl.). An account of spermatogenesis observed in *Blasia pusilla* collected near Chicago. 1. Centrosomes are present at all stages of the mitosis which differentiates the androcytes, and in the androcytes they persist and function as the blepharoplasts. 2. In the transformation of the androcyte into the spermatozoid, the blepharoplast divides repeatedly by simple fission, forming a number of distinct granules which coalesce to form a short lumpy rod. This rod elongates and becomes a more uniform thread bearing two cilia, while the nucleus also elongates in intimate union with it to form the body of the spermatozoid. The present instance is the first in which blepharoplast fragmentation has been reported in a Bryophyte. 3. It is possible that the fission of the *Blasia* blepharoplast, and therefore the more complex fragmentation of the blepharoplasts of *Equisetum*, *Marsilia*, and the Cycads, may be homologized with the normal division exhibited by ordinary centrosomes. A. G.

Life-history of Fossombronia cristula.—ARTHUR W. HAUPT (*Bot. Gaz.*, 1920, **69**, 318–31, 6 pls. and fig.). This paper is summarized as follows:—1. The vegetative body of *F. cristula* consists of a minute, creeping, rather profusely branched thallus which bears genuine leaves in two dorsal rows. 2. The apical cell is dolabrate. Branching is strictly apical. 3. The plants are monœcious, the sex organs occurring in the axes of the leaves. Antheridia and archegonia may occur in the same leaf axis, and there is no time relation in the order of their appearance. They originate from the immediate segments of the apical cell, and their development is strictly acropetal. 4. The antheridia develop according to the usual method found among the anacrogynous Jungermanniales. Variations occur in the order of appearance of the walls in the primary stalk cell. 5. Until the appearance of the first vertical wall young archegonia cannot be distinguished from young antheridia. The first transverse division in the archegonium initial separates the stalk cell from the archegonium proper, and subsequent development follows the usual Jungermanniales type. The cover cell is inactive, six to eight neck canal cells are formed, and the venter is two cells thick before fertilization. The archegonium is of an advanced type. 6. The early divisions of the embryo are transverse, both halves of the fertilized egg contributing to the development of the foot, seta and capsule. A calyptra, three to four cells in thickness, is formed. 7. The sporogenous tissue is differentiated rather early in the history of the sporophyte. The elaters are rudimentary, and each is homologous with a single spore mother-cell, not with a row of them. 8. The sporophyte is primitive.

A. G.

Studies in some East Indian Hepaticæ: Calobryum Blumei N. ab E.—D. H. CAMPBELL (*Ann. of Bot.*, 1920, **34**, 1–12, 1 pl. and figs.). An account of the morphology and reproduction of *Calobryum*. The conclusion is reached that *Calobryum* and *Haplomitrium*, although differing in certain particulars (e.g. the position of the archegonia), are closely related and constitute a special family, Calobryaceæ; but their relationships with the other Hepaticæ are very obscure. Goebel ranges them in a series independent of the other foliose Hepaticæ. The development of leaves has evidently occurred in several quite independent series among the Liverworts; and the Calobryaceæ probably represent the end of such a series, and are not closely related to the foliose Jungermanniales. Whether they are most nearly related to the anacrogynous Jungermanniales, or have been derived from forms more like the Sphærocarpales, is a question. The character of the sporophyte, with its single layer of wall-cells, would suggest the latter hypothesis. The author suggests the establishment of a special order, Calobryales, co-ordinate with the Sphærocarpales, Marchantiales and Jungermanniales. The present distribution of *Calobryum* suggests that the genus was formerly more generally distributed. A. G.

Gemmæ of Tortula mutica Lindb.—B. MURIEL BRISTOL (*Ann. of Bot.*, 1920, **34**, 137–9, figs.). Gemmæ have been recorded for only 17 out of the 620 odd species recorded in Braithwaite's "British Moss

Flora." The gemmæ of a specimen of *Tortula mutica* from North Wales are now described. They were found scattered over the upper surface of the leaves, and also rarely on the protonema. They consist usually of two or four cells, bounded by thick, reddish-brown walls ; they are easily detached and are capable of resting ungerminated. In an allied species, *T. papillosa*, gemmæ occur only on the upper part of the thickened leaf-costa. A. G.

Rhaphidostegium coespitosum (Sw.) and its Affinities.—H. N. Dixon (*Journ. of Bot.*, 1920, **58**, 81–9). An account of the investigation of numerous original specimens collected in various countries, and described as species by a large number of authors. It is found to be quite impossible to maintain them as distinct species ; they show themselves inevitably to be but forms of one species widely spread throughout the tropical and subtropical regions of the southern hemisphere, and extending also into the temperate zone. The oldest type is *Hypnum coespitosum* Swartz (Prodomus, p. 142 [1788]), placed in *Rhaphidostegium* by Jaeger, and now furnished with a synonymy running to nearly three score names. This is one of the most extensive and satisfactory reductions of unnecessary and redundant species that has yet been achieved in bryology. A. G.

Thallophyta.

Algæ.

Attempt to explain the Colourless Series of Flagellates.—A. Pascher (*Ber. Deutsch. Bot. Gesell.*, 1916, **34**, 440–7 ; see also *Bot. Centralbl.*, 1918, **137**, 20–22). A synopsis of the lines followed by the author in his treatment of the fresh-water flagellates in Rabenhorst's "Kryptogamen Flora." He considers that the colourless forms which occur in every series of coloured flagellates are a secondary development of the coloured forms. In every colourless series there are genera and species which stand in the closest relation to the coloured ones, but with a reduced chromatophore apparatus, and having a saprophytic, parasitic, and animal existence, thereby declaring their derived character. Intermediate stages are found ; and it is possible artificially to produce colourless from coloured forms. In all the coloured series animal nutrition occurs secondarily, and leads direct in certain forms to a permanent rhizopodial organization. As opposed to the coloured series of flagellates, there are three series of colourless forms, with characters which, among coloured flagellates, are only found in derived forms. The author considers Protomastiginæ and Pantostomatinæ to be series of flagellates which have been classed together on quite secondary characters, and therefore represent wholly artificial, heterogeneous, polyphyletic groups. The component species are apochromatic and apoplastid forms of the most diverse coloured species, and in some cases are so obviously related that the coloured and colourless should not be separated. The author only continues the present artificial classification for the sake of convenience. He gives an enumeration of the coloured and colourless series. E. S. Gepp.

Peridineæ of New South Wales.—G. I. Playfair (*Proc. Linnean Soc. New South Wales*, 1920, **44**, 793–818, 3 plates and figs.). An account of such Peridineæ as have been found in gatherings of fresh-water algæ from Sydney and Lismore, involving a revision of the plankton of the Sidney Water Supply. Sixteen species (two are new) and twenty-three varieties (many are new) are recorded; most of them are figured and described. Some introductory remarks on grouping of forms, polymorphism and structure are provided. A. Gepp.

Some Species of Fresh-water Plankton from Gandía (Valencia).—Luis Pardo (*Boletin R. Soc. Española Hist. Nat. Madrid*, 1920, **20**, 125–9). An account of some algæ collected at Gandía in November, including an *Oscillatoria*, three Conjugatæ, a desmid, twelve diatoms, and a flagellate, with remarks on their periodicity and requirements. A. G.

Lake of Segrino.—E. Corti (*Nuova Notarisia*, 1920, **31**, 161–6). This note on lacustrine biology contains a list of phytoplankton collected during spring and summer months in fine weather from Lake Segrino, at the mouth of the Assina Valley, in Upper Brianza, south of Lake Como. The lake has no affluent streams, and is fed by springs, only one of which is visible from the bank. The phytoplankton consists of eight Schizophyceæ, three Dinoflagellatæ, five Chlorophyceæ, seven Desmidieæ, and six Diatomeæ. Quantitatively it is much less than the zooplankton, qualitatively the contrary is the case. In the neighbouring lakes of Pusiano and Alserio the animal surpasses the vegetable plankton; in Lake Como the phytoplankton is quantitatively superior. E. S. G.

Campbellosphæra, a New Genus of the Volvocaceæ.—Walter R. Shaw (*Philippine Journ. Sci.*, 1919, **15**, 493–520, 3 pls. and fig.). An account of a new genus of Volvoceæ, *Campbellosphæra* (*C. obversa*), collected near Manila. It is described in detail and figured by photomicrographs. The most peculiar character of the genus is the migration of gonidia, formed early in the development of the embryo, from the outside to the inside of the embryo through the phialopore. The gonidia become very large before dividing. The somatic protoplasts lack protoplasmic connecting fibres. The life-history is described from a series of specimens, showing the salient features of asexual and sexual reproduction. The sexual cœnobia are monœcious. Comparison is made with *Volvox* and closely allied genera, involving some revision of synonymy. *V. aureus* Ehrenb. (1838) is reported to have been collected in California in 1896, and to agree with Klein's ample descriptions (1889–90). The relationships of the Volvoceæ are displayed in a diagram. A. G.

Botrydium granulatum.—C. Janet (*Sur le Botrydium granulatum*. Limoges: Libraire Ducourtieux et Gout, 1918, 6 pp., 1 pl.). An account of the life-history of this alga. *B. granulatum* generally occurs in the form of vesicles, either much elongated or pyriform, arising from the development of a protoplastid which may be either:—1. A purely vegetative cell, developed precociously on the individual from which it

springs; after the collapse of the parent this cell is cast off like a propagule. 2. An asexual planospore which comes to rest, develops a membrane, and undergoes a certain period of rest. 3. A zygote, as yet unobserved by the author, but of undoubted existence. Each of these three varieties of cell develops first into a small vesicle here described in detail, a syncytial blastea formed of juxtaposed plastids, and clothed with a general cuticle. This blastea is the faithful representation of an ancestral primitive stage. It throws out, above, a tube rich in deeply-coloured chromatophores; and, below, a rhizoid containing nuclei and chromatophores, which at once lose their colour. The aerial tube forms a vesicle, of which the author defines three kinds, according to the nature of the cells which they produce. The development of each is described in detail. The essential productiou of the first kind is a number of small cells surrounded with a cellulose cuticle, which after the bursting of the mother-cell are disseminated by rain and germinate. In the second kind asexual planospores are produced which, after escaping from the burst mother-cell, have a short period of activity, and then settle down and germinate in the same way as the cells of the first kind. The third kind of vesicle produces a "gametangium," homologous with the oogonium and spermogonium of *Fucus*. The author has observed all the stages of development except the emission of the flagella of the gametæ, and their subsequent movement and coalescence. In a diagram are sketched out the various aspects of the ontogenesis of the plant.

E. S. G.

Algological Notes. XXV.–XXIX.—N. WILLE (*Nyt Mag. Naturvidenskab. Christiania*, 1918, **56**, 61, 2 pls.). The first of these notes, No. XXV. of the series, deals with variability in the genus *Scenedesmus* Meyen. The author discusses critically the work of former authors, and emphasizes the importance of wide views in regard to the occurrence of variation. He describes the germination of aplanospores in *S. bijugatus* Kütz., the stages of which vary greatly from the normal form. These stages must not, however, be regarded as constituting polymorphism; nor may also the aberrant forms produced under adverse conditions. The vegetative forms of *S. obliquus* Kütz. and *S. bijugatus* respectively are described. The former was found varying in the number of its component cells from one to eight, four and eight being the most common. In *S. bijugatus* the same variation occurred, but the numbers other than four and eight were much more rarely found. In Note XXVI. the germination of the aplanospores in the genus *Cœlastrum* Näg. is described. No. XXVII. gives a list of the fresh-water algæ of Beeren Island, containing fifty-five species and varieties of Chlorophyceæ and Myxophyceæ, sixteen of which are not yet recorded from Spitzbergen. No. XXVIII.: The name of *Lyngbya epiphytica* Wille, a marine species, is changed to *L. Willei* Setchell & Gardner, the former specific name having been previously used in the genus for a fresh-water species. In Note XXIX. the author continues his studies in Agardh's "Herbarium," interrupted since 1913. *Hæmatococcus sanguineus* proves to be *Glœocapsa sanguinea* Kütz. Meneghini's specimens of *Microcystis bullosa* (Kütz.) Menegh. and *M. gelatinosa* Menegh.

were studied, with the result that both of them, together with *Palmella bullosa* Kütz., *Glœcapsa gelatinosa* Kütz., *Aphanothece bullosa* Rabh., and *Glaucocystis Nostochinearum* Itzigs. var. *minor* Hansg., were found to be synonyms of *Glaucocystis bullosa* (Kütz.) Wille. *Aphanocapsa muscicola* (Menegh.) Wille was found to include as synonyms: *Coccochloris muscicola* Menegh., *C. parietina* Menegh., *Palmella muscicola* Kütz., *P. parietina* Näg., *Aphanocapsa parietina* Näg. & Thuret in Wittr. & Nordst. alg. exs. No. 1547, *A. virescens* Rabh. & A. Forti. A study of original material of *Palmella alpicola* Lyngb. shows that it is *Glœocapsa magma* Kütz., and both equal *G. montana* Wille. *Chroococcus pallidus* Näg. is *C. aurantius* Wille. *Palmella hyalina* is *Tetraspora bullosa* Kütz. *Palmella minuta* Ag., with five other species, is *Tetraspora explanata* Ag. *Protococcus natans* Ag. proves to be the germinating zoospores of a filamentous alga, probably *Stigeoclonium tenue* (Ag.) Rabh. var. *uniformis* (Ag.) Kütz. E. S. G.

New Species of Uronema from India.—S. L. Ghose (*Ann. of Bot.*, 1920, **34**, 95–8, figs.). Description of *Uronema indicum*, found in a dirty drain at Lahore, India. It differs from *U. elongatum* in being larger, in the chloroplast running the whole length of the cell, and in the cells being usually broader than long. A. G.

Alga-Flora of some Desiccated English Soils: an Important Factor in Soil Biology.—B. Muriel Bristol (*Ann. of Bot.*, 1920, **34**, 35–80, 1 pl. and figs.). The results of the investigation of forty-four samples of soil from widely separated localities. The material was studied by means of water-cultures; and it was found that there is a widely distributed ecological plant-formation in cultivated soils consisting of moss-protonema and algæ. The most important algæ in this formation are: *Hantzschia amphioxys* (Ehr.) Grun., *Trochiscia aspera* (Reinsch) Hansg., *Chlorococcum humicola* (Naeg.) Rabenh., *Bumilleria exilis* Klebs, and to a less degree *Ulothrix subtilis* Kütz. var. *variabilis* (Kütz.) Kirchn. Other species of typical soil-algæ occurring somewhat less frequently give rise to smaller plant-associations within this formation. In all, 64 species and varieties were found—20 Bacillarieæ, 24 Myxophyceæ, and 20 Chlorophyceæ. The soil-samples had all been subjected to complete desiccation for 4 to 26 weeks before being placed in the cultures; hence those species could be expected to withstand any period of drought that might occur naturally. It seems likely that this extensive algal formation must be of considerable economic importance in the biology of the soil. Six new species or varieties are described, 16 species already known are newly recorded for the British Islands, and a number of new or interesting stages are depicted in the life-histories of certain species already known, especially in connexion with the germination of the spores of some blue-green algæ. The final section of the paper contains a short account of each of the species found in the cultures. Further, in three tables are displayed the botanical analyses of the various samples of soil. A. G.

Roya anglica G. S. West, a new Desmid; with an Emended Description of the Genus Roya.—William J. Hodgetts (*Journ. of*

Bot., 1920, **58**, 65–9). A discussion of the distinguishing characters of the genus *Roya* by which it can be separated from *Closterium*. These are mainly two :—(1) The simple structureless nature of the cell-wall; and (2) the fact that division of the chloroplast into halves is delayed until the cell has reached mature age, or even until it is about to divide. A modified Latin description of *Roya* is given, and the new species *R. anglica* is described. The latter was gathered near Birmingham in the spring of 1916 in very shallow water, and has never been found in such abundance again. It was almost a pure growth, affording numerous cases of conjugation and thousands of zygospores. A. G.

Studies on the Chloroplasts of Desmids. III.—X. The Chloroplasts of Cosmarium.—NELLIE CARTER (*Ann. of Bot.*, 1920, **34**, 265–85, 4 pls. and figs.). An illustrated account of the chloroplasts found in *Cosmarium*. In most species these are axile, in a few they are parietal. In the former either one or two chloroplasts occur in each semi-cell, and very often in the axis of each chloroplast there is typically one pyrenoid; the actual number of pyrenoids depends on the individual. Many of the smaller species have a single chloroplast in each semi-cell consisting of a central axis, containing typically one pyrenoid from which radiate either four more or less forked plates or a number of simple ridges or string-like outgrowths. In *C. diplosporum* there is a rough kind of parietal network arising from the lateral expansion of the ends of the chloroplast rays extending from the central axis. In *C. pseudopyramidatum* the plates arising from the central axis containing the central pyrenoid or group of pyrenoids are very complicated in form and irregular in arrangement. *C. pyramidatum* differs from the previous species in having a more delicate axis in the arrangement of its pyrenoids, which rarely occupy the centre of the chloroplast. *C. achondroides* differs from *C. diplosporum* in having pyrenoids in the lateral lobes of its chloroplast as well as in its central axis. In *C. pseudoconnatum* the chloroplast is axile with four wedge-shaped masses radiating towards the periphery, each mass possessing typically one pyrenoid. *C. ornatum* and *C. Ralfsii* differ from all the other species examined in having scattered pyrenoids, rarely more than three in *C. ornatum*, but more numerous in the larger *C. Ralfsii*; and the chloroplast of the latter resembles those of certain thick-celled species of *Micrasterias*. Many species of *Cosmarium* have two axile chloroplasts in each semi-cell, there being one point of pyrenoid formation in each chloroplast. The axis which contains the pyrenoid or group of pyrenoids is surrounded by a number of radiating plates or more numerous string-like projections, whose peripheral edges in many cases spread out over the internal surface of the cell-wall, either in irregular parietal masses or as a more or less continuous reticulated film. Two forms of *C. præmorsum* were examined, containing one and two chloroplasts in a semi-cell respectively. *C. Brebissonii* has most peculiar and variable chloroplasts, sometimes parietal, sometimes distributed throughout the cell. A few species have chloroplasts entirely parietal, with scattered pyrenoids, the number of both being variable. A. G.

Catalogue of the Collections of Diatoms and Fungi in the Pontifical Academy in Rome.—G. Antonelli (Rome: 1918, 171 pp.). A catalogue of the diatoms of Count Francesco Castracane and of Dr. M. Lanzi preserved in the Accademia Pontificia Romana dei Nuovi Lincei. It includes the entire collection of Castracane; and a large part of Lanzi's collection of diatoms, together with all his microscopical preparations of fungi. The arrangement of the slides and material into groups was carried out by Cav. F. Gatti. The Castracane collection contains 4682 preparations, each of which is here recorded, with the name of the species, locality, and preparer. Preparations other than diatoms bring the Castracane total to 4738 slides. There is a catalogue of 557 samples of diatomaceous earth, with localities, and a further list of recent material, bringing the number of samples to 1191. Then follow indices to the genera and species, to the geographical distribution, to the expeditions and cruises represented, etc. The Lanzi collection, which is catalogued in the same way, contains 633 preparations of diatoms. E. S. G.

Campylonema lahorense, a new Member of Scytonemaceæ.—S. L. Ghose (*New Phytologist*, 1920, **19**, 35–9, figs.). A description of a blue-green alga which appears during the August rains at Lahore, and forms vast strata on damp lawns, etc. The sheath of the filaments embedded in the mud is inconspicuous, but is strongly developed on the upward curved aerial filaments. Though previously referred to *Tolypothrix*, the plant shows itself to be quite distinct from that genus by its frequent intercalated heterocysts, its lack of pseudobranches, and the curvature of its filaments. It falls more suitably into *Campylonema*, but is quite distinct from the Bombay species, *C. indicum*, which is epiphytic on hepatics. A. G.

Some Tuscan Myxophyceæ.—A. Forti and M. Savelli (*Bull. Soc. Bot. Ital.*, 1917, 6 pp.). A list, with localities, of forty-seven species of Tuscan Myxophyceæ, almost all collected from the environs of Pisa, and forming a preliminary publication to a work on the freshwater algæ of the district of Pisa. E. S. G.

Myxophyceæ from Italian Somaliland.—A. Forti (*R. Ist. Studi Sup. Firenze*, 1916, p. 188). A few remarks extracted from the Report by E. Chiovenda on the Botanical Collections of the Stefanini-Paoli Mission. The author records *Nostoc commune* Vauch. var. *flagelliforme* B. et F., of which he gives a certain amount of synonomy, from Salagle, in Jubaland. A previous record is Smithfield, in the Orange River Colony, and the distance between the two stations leads to the inference that the variety is probably diffused throughout the continent. It does not correspond with the more capilliform varieties of typical *Nematonostoc rhizomorphoides*, but recalls well the clathrate thalli distributed by Collins as No. 1901 of his "Phycotheca Boreali-Americana," which demonstrate the slight systematic value of this distinction. This variety is eaten in China under the name of Fahtsai. The distribution includes the Pyrenees, Bohemia, Texas, Montana, Mexico, and China. E. S. G.

Observations on Monosporangial Discs in the Genus Liagora.—M. A. Howe (*Bull. Torrey Bot. Club*, 1920, **47**, 1–8, 1 pl., figs. in text). An explanation of the structures briefly described and figured by Kützing in 1858 (Tab. Phyc. VIII., pl. 90). The structures in question are small flat orbicular discs lying on the general surface of the plant or somewhat immersed among the assimilatory filaments. They are of a deeper red colour than the main *Liagora* plant; they send down few or numerous root-hairs from their ventral (proximal) surface in among the assimilatory filaments; and they bear on their dorsal (distal) surface a few sporangia, the contents of which remain undivided, so that they may be referred to as monosporangia. Long, colourless, gelatinizing hairs may usually be seen arising from this outer or dorsal surface. It might be supposed that they are either independent organisms or perhaps obligate epiphytes of various species of *Liagora*; or that they result from the germination of carpospores and represent a non-sexual alternating phase in the life-history of the genus. But the truth seems to be that these discs arise from gonidia, gemmæ, or aplanospores derived from the terminal or subterminal cells of the assimilatory filaments of the *Liagora*; and more often on male than on female plants. The development of the discs varies in certain details according to the species they represent. The author has made a prolonged and careful study of these discs on four of the West Indian species, *L. ceranoides*, *L. valida*, *L. farinosa* and *L. pinnata*, and describes the variations in the development of each. The mature discs are suborbicular and are more or less similar in these four species. Fertile discs are mostly 90–230 μ broad (not including the mucous envelope), though in *L. farinosa*, the largest species of the four named, they may reach a diameter of nearly 400 μ. The monosporangia are ellipsoid, ovoid and obovoid. To what these give rise on germination has not been determined, but there seems to be some ground for believing that they produce monosporangial discs like those from which they sprang. Inferences that young sporelings associated with a *Liagora* represent stages in development of the *Liagora* itself demand vigorous confirmation; but the almost constant association of *Acrochætium*-like forms with various species of *Liagora* is a suspicious circumstance that deserves investigation. Finally, he points out criticisms that may be raised on his conclusions, since, as he frankly acknowledges, he knows of no analogy among other Rhodophyceæ for the state of things here described. He suggests that a study of living material, cultural experiments and cytological investigation would settle the question, although he believes his explanation to be correct. E. S. G.

Appendix to "Oceanic Algology."—A. Mazza (*Nuova Notarisia*, 1920, **31**, 93–160). Further additional notes on species belonging to sub-families Mychodeæ and Callymenieæ, and to the family Rhodophyllidaceæ. The author devotes considerable attention to *Callymenia cribrosa* Harv., describing its structure and perforations, and comparing it with perforated species of Phæophyceæ, *Hydroclathrus*, *Agarum* and *Thalassiophyllum*, as well as with other Florideæ. The two doubtful species of *Meristotheca*—*M. Duchassaingii* J. Ag. and *M. Fergussonii* Grun.

—are considered, but though the author suggests other affinities for them, he does not consider himself justified in placing them in any definite genus, until the limitations of the genera *Meristotheca*, *Carpococcus* and *Euryomma* have been more accurately determined. E. S. G.

Geographical Distribution of the Marine Algæ.—W. A. Setchell (*Science*, N.S., 1917, **45**, 197–204). An address to the Botanical Section of the American Association for the Advancement of Science. The author has made a survey of the entire literature of the marine algæ, and noted the influence of various writers in developing the different lines of geographical study. He considers that the work done on the following five lines bears most directly on geographical distribution, viz. taxonomy, morphology and development, floristics, physiology, and geographical distribution. The work of various authors is briefly discussed. As a summing up of the general results and an attempt to determine the general subdivisions of the coast-lines to satisfy all requirements of geographical distribution, the following divisions are suggested :—A. *Climatic.*—I. *Zones*, regulated by temperature of the warmer months, especially to be determined by the mean summer temperatures or in practice by the isotheral lines at intervals of 5° C. II. *Regions*, purely geographic segregations under zones. III. *Provinces*, subdivisions of regions according to mean winter temperatures, in practice by isocrymes, 5° apart or less. IV. *Districts*, subdivisions under provinces according to geographical remoteness and varying physical conditions of a general nature. B. *Topographical.*—V. *Formations*, aggregations of algæ of same general form, depending particularly upon substratum. VI. *Associations*, aggregations depending for general likeness of form, etc., upon depth (belts), salinity, light, aeration, etc., generally characterized by the predominance of a single, or, at most, of a few species. E. S. G.

Marine Flora of the Pacific Coast.—W. A. Setchell (*Nature and Science on the Pacific Coast.* San Francisco : P. Elder and Co., 1915, 177–84). A more or less popular and condensed consideration of a large subject, touching only on salient features and giving general directions for further study. The area is divided into zones which are geographically defined : Upper Boreal, Lower Boreal, N. Temperate, N. Subtropical, Tropical. Each zone has a flora, the general aspect or facies of which is distinct and characteristic. All the main groups of algæ are well represented, but the most conspicuous and famous are the Laminariaceæ of which the author gives details of interest. Marine phanerogams, lichens and fungi are also recorded. A short list of bibliography is appended. E. S. G.

Utilization of Marine Algæ.—C. Sauvageau (*Encyclopédie Scientifique.* Paris : O. Doin, 1920, vi and 394 pp., 26 figs. in text). A description of the uses which may be made of marine algæ. In the introduction the author refers to the mode of life of the seaweeds, their scientific importance, their chemical analysis, and the biological causes of errors made by analysts. The first chapter is devoted to a discussion of the weed (wrack) and the manner of collecting it. Three sorts are officially recognized, and have been legislated for in France since 1681 :

weeds thrown up on the shore, those which can be cut *in situ* at low water, and those collected from a boat in deeper water. The rights of the French people along the shore, who use the wrack for agricultural purposes and for fuel, are carefully defined. Also an account is given of the progress of the industry in the United States. In the second chapter the author discusses in detail the application of wrack to agricultural purposes in various countries. It promotes the growth of excellent potatoes and barley, and has been of great use in checking the ravages of Phylloxera in vineyards. Among its advantages is its freedom from noxious insects, seeds, etc., which are common in ordinary farmyard manure. He discusses the chemical value of the giant Laminariæ harvested in the Pacific, quoting various analyses, and refers to the methods of drying, etc., which is carried out on a large scale and with great success. The third chapter deals with the industrial utilization of the Brown algæ, and describes the commercial uses to which they have been put to in old days; the processes of calcination and lixiviation; the extraction of soda, potash, iodine; algin and its properties; algulose and algæ-paper; norgine; process of fermentation; sugars; pectic compounds (algin, fucin, fucoidin); intracellular substances (mannite, fucosan, laminarin); and, finally, the use of *Zostera* and *Posidonia* in the making of paper. In the fourth chapter the author discusses the industrial utilization of the Red algæ under the headings: iodine; mucilaginous and gelatinizing properties; fabrication of funori and kanten in Japan; carragheen, its collection, properties and uses; chemical nature of the mucilages. Chapter V. contains an account of the utilization of marine algæ for food of man and of animals (experiments in feeding French horses during the War), with an interesting account of marine herbivores, the blue diatom and the green coloration of oysters. The sixth and final chapter describes various uses of marine algæ and their culture; the use of dried stipes of Laminariæ; of algæ for fishing line, and as bait for certain fishes; red algæ and Tyrean purple; medical use of certain algæ; preparation of algæ for herbaria, etc.; and culture of marine algæ in Great Britain and Japan. The work of Lefranc is cited as showing that Tyrean purple is the product of two gastropods and not of algæ. A bibliography, a table of authors' names, an index, and a synopsis complete this interesting work.

E. S. G.

Feeding of Horses with Marine Algæ.—C. Sauvageau and L. Moreau (*C.R. Acad. Sci. Paris*, 1919, **168**, 1257–61). Describes the experiments made in 1918 in France to make good the scarcity of forage, especially oats, for horses by feeding them on marine algæ. Horses which had been placed on the sick list were first treated, their oats ration being replaced by algæ. They recovered. Healthy horses were then gradually trained to accept the new food, both chemically prepared and in a natural state. The algæ employed were *Fucus serratus* and *Laminaria flexicaulis*. The results were excellent, and the horses under observation were able to do full work without any ration of oats. *L. saccharina*, however, was obstinately refused. This fact had been noted by former observers, who had recorded the feeding of Norwegian

and Lapp beasts on marine algæ. The conclusion is therefore that *L. flexicaulis* and *Fucus serratus* constitute an excellent food, the only drawback being that it is as a rule at first difficult to digest. But in the course of a week or two digestion becomes more and more complete, till at last the food not only supports life, but gives strength for work, and even appears to aid the assimilation of the ordinary food. E. S. G.

British Charophyta. Vol. I. Nitellæ.—J. Groves and G. R. Bullock-Webster (London: Ray Society, 1920, xiv and 141 pp., 20 pls., figs. in text). The first volume of a monograph of the British Charophyta, which will be completed in two volumes. The first embraces Nitellæ (*Nitella* and *Tolypella*), the second will include Charæ (*Nitellopsis*, *Lamprothamnium*, and *Chara*). In an introduction the authors discuss the rank and position of the group, its antiquity, geographical distribution, conditions of growth, economic uses, etc. Then follows a detailed and illustrated account of the structure and development of the Charophyta; a conspectus of the distinctive characteristics of the oospores and membranes of the British Charophyta; a glossary; and a table of Latin adjectival names. The rest of the book is devoted to the systematic treatment, which opens with a history of the identification of Charophyta in this country, reprinted from the *Journ. of Bot.*, 1880. Keys to the five genera and thirty-two species are followed by a detailed systematic account of the genera *Nitella* and *Tolypella*. A full list of synonymy, diagnosis, distribution, and critical remarks are supplied under each species. The twenty plates exhibit germination, stages of growth, decoration of membranes, and the habit and structure of each species described in this volume. E. S. G.

Preliminary Note on a Differential Staining of the Cytoplasm of Characeæ.—R. Hitchcock (*Bull. Torrey Bot. Club*, 1919, **46**, 375–9). Describes the result of staining the cells of two species of *Nitella* with a dilute solution of neutral red. The central cylinder is seen to become a pronounced cardinal red or wine colour, bordered on either side by a narrow line of green. Within the coloured cylinder, or vacuole, are numerous suspended granules, etc., of undetermined nature, which quickly take the stain. In the green border the chloroplasts may be seen regularly arranged along the cellulose wall, and next to that layer is, all coloured, one of denser cytoplasm, carrying small, uncoloured granules and some spherical plasmic bodies in suspension, in active cyclosis, closely following the cell-wall. Further details of the cell-structure are discussed, and the manner in which the colouring matter makes its way into the vacuole of the *Nitella* cell. A peculiar plasmic structure in the *Nitella* cell is then described, consisting of curious spherical masses of granular matter, of extreme plasticity, greatly varying in size up to 0·1 mm. diam. The granules are in a state of constant agitation, as though the mass were seething with life. The author describes them in detail, and suggests they may be connected with the development of chloroplasts. These were observed in two species of *Nitella* and one of *Chara*. The author suggests these structures may be the same as those imperfectly described by Goeppert

and Cohn (*Bot. Zeit.*, 1849), and by them associated with the formation of starch. In a supplementary note the author states that the long hyaline rhizoids of *Nitella* afford a more favourable means of demonstrating the selective colouring, the vacuole becoming deeply coloured, while the thin uncoloured outer stream is in active rotation. The vacuole-contents may be strongly coloured by reason of an acid reaction. Ordinary water, or distilled water, is usually slightly alkaline, slowly changing neutral red to yellow or orange. When *Nitella* is grown in water slightly acidified with acetic acid the vacuole becomes much more deeply coloured than the culture solution. E. S. G.

Fungi.

New Peronospora for Italy (Peronospora Radii De Bary) and its Floral Deformations on Matricaria Chamomilla.—Nicola Belosersky (*Atti Accad. Sci. Venet.-Trent.-Istr.*, 1919, **10**, 111–6). The author sums up the deformations caused by the fungus as reported by Molliard —the mechanical action exercised by the mycelium on dividing cells; torsion of the floral peduncle owing to the formation of secondary tissue; modifications due to alterations in nourishment, such as the atrophy of the sexual organs and transformation of the floral ligules into floral tubes, etc. The latter deformations more especially were confirmed by the author, and are described in detail. A. Lorrain Smith.

Infection Experiments on Tomatoes with Phytophthora terrestria, etc.—J. Rosenbaum (*Phytopathology*, 1920, **10**, 101–5). The fungus causes a rot of the fruits, these being attacked where they touch the ground. If the fruit is only slightly damaged, the fungus can be killed by immersion of the tomatoes in 60° C. water for one and a half minutes. The addition of 1–5000 copper sulphate to infected soil will prevent infection from the soil to the tomatoes. A. L. S.

Zoophagus insidans.—Robert Mirande (*Bull. Soc. Mycol. Fr.*, 1920, **36**, 47–53, 2 figs.). This fungus, a parasite on rotifers and other animalculæ, was discovered in Austria in 1911. Mirande has recently found it in an aquarium in which aquatic mosses were cultivated. The fungus has a long non-septate wide filament similar to that of a *Saprolegnia*. At varying intervals there are narrow branchlets or projections at right angles to the main filament. It is by means of these branchlets that the fungus captures the animalcules and retains them until their contents are exhausted. The author seems to agree with the suggestion that the fungus is allied to *Saprolegnia*. He compares it with *Arthrobotrys oligospora*, which captures Nematodes. A. L. S.

Chytridine Parasite of Lucerne.—Fron and Laonier (*Bull. Soc. Mycol. Fr.*, 1920, **36**, 53–61, 1 pl., 1 fig.). The fungus *Urophlyctis Alfalfæ* causes deformation of the host plant. It invades the cells, causing them to enlarge; the cellular membrane is thickened, and the

final destruction of these cells gives rise to cavities in which are formed resting-bodies, termed "chronisporocystes." No sexual process was observed. A. L. S.

Development of the Spinach Mildew (Peronospora Spinaciæ).—JAKOB ERIKSSON (*Arkiv. Bot.*, 1919, **15**, No. 15, 1–25, 3 figs., 4 pls.). An account of the geographical distribution of the fungus is given. It was described first in England as *Botrytis effusa* and confused with *Peronospora effusa*. It has been recorded in most European countries and America. Eriksson discusses and condemns the theories held by various workers as to the over-wintering of the fungus. He then proceeds to give the results of his own cytological researches on the spinach plant. He traces the beginning of the fungus to a mycoplasm in the cell of the host. The history of development is followed through the escape of the mycoplasm from the cell, the formation of hyphæ and sexual organs, and the production of conidiophores and conidia, which in turn initiate new infections. A. L. S.

Studies in Discomycetes. II.—JESSIE S. BAYLISS ELLIOTT (*Trans. Brit. Mycol. Soc.*, 1920, **6**, 263–8, 30 figs.). The writer publishes critical notes on a number of rare species; she gives a new and revised description of *Dasyscypha conformis*, and she judges that *Orbilia coccinella* does not differ from *O. leucostigma* var. *Xanthostigma*. Associated constantly with *Pyrenopeziza plicata* is to be found *Phoma conicola* sp. n. *Mollisia Populi* sp. n. was found at Tanworth-in-Arden.
A. L. S.

Formation of Conidia and the Growth of the Stroma of Daldinia concentrica.—JESSIE S. BAYLISS ELLIOTT (*Trans. Brit. Mycol. Soc.*, 1920, **6**, 269–73, 9 figs.). The author watched the development of the conidia both in nature and in artificial cultures. Observations are recorded on the development of the stroma, the formation of perithecia, and the discharge of the ascospores. The fibrous nature of the stroma is due to the arrested growth of perithecia. Any increase in humidity brings about active growth which leads to the formation of a new perithecial layer and atrophy of the preceding zone. A. L. S.

Aspergillus fumigatus, A. nidulans, A. terreus sp. n., and their Allies.—CHARLES THOM and MARGARET B. CHURCH (*Amer. Journ. Bot.*, 1918, **5**, 84–104, 3 figs.). The authors give an account of their cultural researches on these three related Aspergilli. They fall into two divisions:—*A. fumigatus* with simple sterigmata, and the others with compound sterigmata. Each *Aspergillus* also represents a group. The authors give descriptions of them all, a key to the species, and a descriptive list of published species belonging to this well-marked series.
A. L. S.

Spore Formation in Philocopra cœruleotecta Rehm sp. n.—HALLY JOLIVETTE SAX (*Amer. Journ. Bot.*, 1918, **5**, 61–78, 3 pls.). The fungus has a minute perithecium and polyspored asci. The research was undertaken to determine the manner of spore formation in such an ascus,

in order to see if the development had any affinity with spore formation in a sporangium. The author describes his methods and cultures, and finally gives a summary of the points determined :—Spore formation proceeds as in the eight-spored ascus ; there is successive nuclear division until the final number is reached, then the spore is delimited, as in other species, by the astral hairs which bend back and fuse to form the spore membrane. There is therefore no indication of any phylogenetic relationship between the ascus and the sporangium of the Phycomycetes.

A. L. S.

Audibility of Spore Discharge in Helvella elastica.—R. E. Stone (*Trans. Brit. Mycol. Soc.*, 1920, **6**, 294). The writer brought to his laboratory a basket full of these fungi, and the following day he detected a hissing sound at a distance of five to six feet. On lifting the cover of the basket he noted a spore-puff with a distinct hiss. The puffs occurred at intervals and always accompanied by a hissing sound.

A. L. S.

Diplocystis and Broomeia.—I. B. Pole Evans and Averil M. Bottomley (*Trans. Roy. Soc. S. Africa*, 1919, **7**, 189–92, 5 pls.). The authors describe a new species, *Diplocystis Junodii*, sent from Portuguese E. Africa, and called by the natives "Fole da mangapfi," viz. the tobacco of the hawk. The authors compare *Diplocystis* with *Broomeia* ; the two genera are nearly related, but differ in the form of the stroma, which, in the latter, is thick and somewhat columnar, while in *Diplocystis* it is saucer-like. It has been stated that *Broomeia congregata* grows on rotten wood, but the authors find it on living trees of *Acacia karoo*, and the trees thus associated were gumming freely from the main stem.

A. L. S.

Furrows and Germinating Pores.—J.-E. Chenantais (*Bull. Soc. Mycol. France*, 1920, **36**, 29–33, figs.). The writer criticizes as a character of taxonomic importance the presence of a pore or furrow in spores of Xylariaceæ. Vincens had published a paper which insisted on the importance of the furrow as indicating relationship. Chenantais considers that the furrow is simply a mode of dehiscence in brown thick-walled spores, and may occur in unrelated genera. A. L. S.

Development of the Geoglossaceæ.—G. H. Duff (*Bot. Gaz.*, 1920, **69**, 341–6.) The writer traces the growth of *Cudonia lutea* and *Spathularia velutipes* from the earliest stages. He finds at the centre of a minute cushion of hyphæ certain filaments conspicuous by their size and staining qualities ; they are the precursors of coiling procarps which arise from them at a later stage. In *Spathularia* generative hyphæ appear much later, as do the procarps. In *Cudonia* the procarp produces "typical multiseptate trichogynes which penetrate the envelope, projecting into the air for a short distance. Spermogonia and spermatia are entirely lacking, and it is not thought that the trichogynes are functional organs." The writer contrasts this development with that of the *Cladoniæ* among lichens as described by Nienburg. A. L. S.

List of the Discomycetes of Perthshire.—JAMES MENZIES (*Trans. Perthshire Soc. Nat. Sci.*, 1919, 72–7). The author has brought together all the Discomycetes that have been recorded in that county; those from the Perth district were found by himself. The list is long and representative of British species. With the list is associated the description of a rare Myxomycete, *Lindbladia effusa*. It grew on sawdust, and when in full vigour looked like a great splash of tar. A. L. S.

South African Perisporiaceæ. II.—ETHEL M. DOIDGE (*Trans. Roy. Soc. S. Africa*, 1919, **7**, 193–7, 3 figs.) reviews and corrects the description of *Meliola torta* Doidge. She finds on the same host a second species, *M. scabra* and *Asterina* sp., also another fungus, *Perisporina melioliicola* sp. n., parasitic on the mycelium of *Meliolæ*. A. L. S.

South African Perisporiaceæ. III.—ETHEL M. DOIDGE (*Trans. Roy. Soc. S. Africa*, 1919, **8**, 107–10, 1 pl.) describes four species of *Meliola* from Natal and the eastern part of the Cape Province, hitherto unrecorded from South Africa. Full descriptions and figures of these species are given. A. L. S.

South African Perisporiaceæ. IV.—ETHEL M. DOIDGE (*Trans. Roy. Soc. S. Africa*, 1919, **8**, 111–5, 2 pls.) in this contribution gives diagnoses of six new species of *Meliola*, two species of *Zukalia*, and *Phæodimeriella asterinicola* sp. n., the latter parasitic on the mycelium of *Asterina*. All of them grew on leaves from various regions of South Africa, but mostly from Natal. A. L. S.

South African Perisporiaceæ. V.—ETHEL M. DOIDGE (*Trans. Roy. Soc. S. Africa*, 1919, **8**, 137–43, 2 pls.) describes a number of new species of *Meliola* from Natal, and lists a number of species already recorded from South Africa or elsewhere on the same or on different hosts.
A. L. S.

Mycological Notes.—ETHEL M. DOIDGE (*Trans. Roy. Soc. S. Africa*, 1920, **8**, 117–9). The paper contains notes on *Asterodothis solaris* (K. and Cke.) Th., a frequent parasite on leaves of *Olea verrucosa* in South Africa. The author gives several new records for other leaf-fungi, and describes two new species. A. L. S.

Meliolaster, a New Genus of the Microthyriaceæ.—ETHEL M. DOIDGE (*Trans. Roy. Soc. S. Africa*, 1920, **8**, 121–3) places the new genus in the group of Hemisphæriales, as it bears a perithecium or "thyriothecium" of hemispherical form. *Meliolaster* combines characters of *Meliola* and *Asterina*; it grows on leaves of *Piperis capensis* in Natal.
A. L. S.

Descriptions of New Fungi Imperfecti from the Philippines.—H. DIEDECKE (*Ann. Mycol.*, 1916, **14**, 62–4). There are eight new species in the list and two new genera, *Bakerophoma* and *Macrophomella*, both related to *Phoma*, but the pycnidia seated on a subiculum, or furnished with setæ at the apices. A. L. S.

Contribution to the Study of the Brazilian Mycological Flora.—A. Maublanc (*Bull. Soc. Mycol. France*, 1920, **36**, 33–43, 3 pls.) made a large collection of fungi, more particularly of plant parasites, during a two years' residence in Brazil. His intention is to publish a complete list of his plants, but meanwhile he is issuing descriptions of new fungi. These include Pyrenomycetes and Sphæropsideæ, with one new genus, *Uropolystigma* (Nectriaceæ). A. L. S.

Phomopsis juniperovora, a New Species causing Blight of Nursery Cedars.—Glenn Gardner Hahn (*Phytopathology*, 1920, **10**, 249–53, 1 fig.). The fungus occurs on the needles and stems of *Juniperus virginiana*. The author noted two types of spores, the usual oblong or ellipsoid spores, and long narrow curved spores, which he terms scolecospores. A. L. S.

Study of Fusarium.—Z. Paravicini (*Ann. Mycol.*, 1918, **16**, 300–19, 1 pl.). The author set out to examine the *Fusaria* that cause rottenness of fruits, and to observe the occurrence of anastomosis and its significance. The principal agent in causing the rot is *Fusarium putrefaciens*. Paravicini by his cultures obtained growths of two new species, *F. luteum* and *F. rubrum*; full particulars of these are given. He observed anastomosis in the mycelium and between spores. There was no evidence of any sexual act. Anastomosis took place unfailingly in the hanging-drop cultures, but still more surely if the drop became concentrated by evaporation. A. L. S.

New Genus of Hyphomycetes.—Romualdo G. Fragoso (*Bol. Real Soc. Esp. Hist. Nat.*, 1920, **20**, 112–4, 3 figs.). The new genus belongs to the *Dematieæ*, and is characterized by large septate spores curved at the ends. It grows on *Sphagnum squarrosum*, and has been named *Casaresia sphagnorum*. A. L. S.

Puccinia obscura and Related Pucciniæ on Luzula.—P. Dietel (*Ann. Mycol.*, 1919, **17**, 48–58). *Puccinia obscura* is distinguished from other forms on *Luzula* by the large uredospores. Dietel has tested the size of these spores by many measurements, comparing those from different *Luzulæ*. He made the same measurements and comparisons with the teleutospores, noting in both series of experiments the colour as well as the size. A. L. S.

Structure of the Uredinium in Pucciniastrum Agrimoniæ.—C. A. Ludwig and C. C. Rees (*Amer. Journ. Bot.*, 1918, **5**, 55–60, 1 pl.). In this species the uredinium begins as a small aggregation of hyphæ under the epidermis, which is finally burst. The mesophyll tissues of the host are scarcely affected. At maturity the sorus is bounded above and at the sides by a peridium of somewhat overlapping, thin-walled cells, but of considerable tensile strength, as the sorus maintains its shape and the only escape for the spores is by a central ostiole. When this stage is reached the peridium begins to disintegrate. The mature spores are catenulate and echinulate. The authors suggest new methods of arrangements in the *Pucciniastratæ* to which this rust belongs.
A. L. S.

Short Cycle Uromyces of North America.—G. R. Bisby (*Bot. Gaz.*, 1920, **69**, 193–217, 1 pl.). The writer gives an account of the genus, and of work—cytological and other—done on the genus. There are eleven species of short-cycle *Uromyces* in N. America, and he gives a detailed description of each species. They occur in the higher and warmer portions of the Continent and upon seven widely separated host families. Morphological evidence shows they are not inter-related, but are rather associated with other rusts upon the same or related hosts. A. L. S.

Two Russian Gymnosporangieæ.—Jakob Eriksson (*Arkiv. Bot.*, 1919, **15**, No. 20, 1–23, 2 pls., 1 col.). One of these rusts has been determined by Eriksson as *Gymnosporangium Oxycedri* Bres. He was able to produce the æcidium stage on *Cratægus monogyna*, *C. nigra* and *Mespilus germanica*. Other *Pomaceæ*—*Sorbus*, *Pyrus*, etc.—remained immune. Another, *Gymnosporangium tauricum* sp. n., formed teleutospores on *Juniperus excelsa*. It formed æcidia on *Cratægus monogyna* and spermogonia on *Cydonia vulgaris*. Other *Pomaceæ*—*Pyrus*, *Mespilus*, *Sorbus*, etc.—were immune to infection. A. L. S.

Uredinales of Guatemala based on Collections by E. W. D. Holway.—J. C. Arthur (*Amer. Journ. Bot.*, 1918, **5**, 325–36, 420–46, 462–89). Arthur has published his results in three different papers. A total of 600 rust specimens was collected by Holway during three successive visits. In the first paper an account is given of the different expeditions, and the Coleosporaceæ and Melampsoraceæ are described (twenty-two species), several of them new to science. The second paper deals with Æcidiaceæ, exclusive of *Puccinia*, bringing the total up to 101 species; the third paper takes up *Puccinia* exclusive of species on Carduaceæ. He finds that in the last group the most interesting are the species on grasses; such rusts are less common in the tropics. Holway secured fifteen species, three of them undescribed. Holway was also able to connect up an æcial form on *Eupatorium* with a grass rust on *Ægopogon*. A. L. S.

Selected Cycles in Gymnoconia Peckiana.—G. F. Atkinson (*Amer. Journ. Bot.*, 1918, **5**, 79–83). This rust was considered to be a short-cycle species with two generations. It is associated with *Cæoma nitens*, a rust of raspberry plants. It has also been demonstrated that the cycle may be further shortened by the æcidiospores germinating in the manner normal for teleutospores, i.e. by the production of promycelia and sporidia. The author confirmed this finding and discusses the importance and the position in classification of *Gymnoconia Peckiana*. A. L. S.

Dothideaceous and other Porto Rican Fungi.—F. L. Stevens (*Bot. Gaz.*, 1920, **69**, 248–57, 3 figs. and 2 pls.). Stevens collected the fungi described in Porto Rico; they are all plant fungi occurring on leaves or stems of various trees. There are a number of new species and one new genus *Halstedia*, the asci of which are borne in a locule in a superficial stroma. A. L. S.

Genus Clavariopsis Holt.—N. PATOUILLARD (*Bull. Soc. Mycol. France*, 1920, **36**, 61–3, 2 figs.). The genus was established by Holtermann to include species of *Tremella* with a *Clavaria* form of growth. Three species from tropical countries have been determined as belonging to the genus. Patouillard now describes a fourth from the Philippines collected by Professor Otto Reinking. This species is distinguished by the formation of new basidia arising from a continuation of the fertile filament from the base of that previously formed. A section shows a whole series of these basidia in tiers up to the exterior of the plant. The fungus grows in groups of upright simple or branched stalks up to 2 cm. high. A. L. S.

Higher Basidiomycetes from the Philippines and their Hosts. I.—O. A. REINKING (*Philippine Journ. Sci.*, 1919, **15**, 479–90). The list includes the larger fungi that grow on living or dead trees. The former being parasitic are more restricted in their hosts. *Schizophyllum commune*, a saprophyte, is recorded on fifteen different woods. The fungi were identified by N. Patouillard. A list of hosts is also given with their parasites. A. L. S.

Cytology of Eocronartium muscicola.—HARRY M. FITZPATRICK (*Amer. Journ. Bot.*, 1918, **5**, 397–419, 3 pls.). A detailed study of the cytology of the fungus in all its stages. All the hyphæ seem to have binucleate cells. The nuclei fuse in the young basidia. The various phases of nuclear division are described. Nothing is known of the nuclear history which follows spore germination and precedes the appearance of the binucleated series of cells in the hyphæ. The fungus is closely related to the Uredinales, and there may be a cell fusion at one stage which would provide the two nuclei. A. L. S.

Hymenomycetes of France.—H. BOURDOT and A. GALZIN (*Bull. Soc. Mycol. France*, 1920, **36**, 43–7). An account of species of *Asterostroma* and *Asterodon*. The Asterostromeæ form a small group characterized by the stellate cystidia analogous with the cystidia of Hymenochæte, etc. Three species of *Asterostroma* are recorded for France, and one of *Asterodon*. They are all more or less brightly yellow in colour. A. L. S.

Polyporaceæ of Bengal. III.—S. R. BOSE (*Bull. Med. Coll. Belgachia*, 1920, 1–8, 6 pls.). The writer gives good popular descriptions of twelve species of more or less common occurrence. The paper forms part of a series by the same author. A. L. S.

Development of some Exogenous Species of Agarics.—GERTRUDE E. DOUGLAS (*Amer. Journ. Bot.*, 1918, **5**, 36–54, 7 pls.). A study of development in *Mycena subalcalina*, *Hygrophorus* sp., and *Entoloma* sp. In these Agarics the fruit-body is at first a button of interwoven hyphæ. Differentiation arises by apical growth, and the hymenophore originates in the annular furrow which is at the junction of stem and pileus. Gills develop as in endogenous forms, except that they are exposed from the beginning. A. L. S.

Some New Species of Inocybe.—Geo. F. Atkinson (*Amer. Journ. Bot.*, 1918, **5**, 210–8). The author gives diagnoses of twenty-five species of *Inocybe* new to science. They were all collected at various dates during the last twenty years or so in New York State, mostly at Ithaca or in the grounds of Cornell University. Atkinson pays special attention to the cystidia as diagnostic characters. A. L. S.

Novæ Fungorum Species. XV.—H. and P. Sydow (*Ann. Mycol.*, 1917, **15**, 143–8). The fungi described in this contribution were sent from many different regions, Japan, South Africa, etc. One new genus is recorded, *Actinomyxa*; the species *A. australienses* (Microthyriaceæ) was sent from Mr. Wilson in Australia, and grew on leaves of *Lasiopetalus*. A. L. S.

Notæ Mycologicæ. Series XXIII.—P. A. Saccardo (*Atti Accad. Sci. Venet.-Trent.-Istr.*, 1919, **10**, 57–94). These notes deal with Philippine fungi collected by C. F. Baker. The list comprises 149 fungi, 109 of which are new to science, the new species belonging largely to Fungi Imperfecti. There are also four new genera: *Reyesiella* (Uredineæ), near to *Ravenelia*, but differing in the absence of sterile cells, etc.; *Ferrarisia* (Perisporiaceæ); *Trotteria* (Sphærioideæ); and *Sporostachys* (Hyphomycetes). The species all come under the micro-fungi group. A. L. S.

Tympanopsis and some other Genera.—F. Theiszen (*Ann. Mycol.*, 1917, **15**, 269–77, 1 fig.). Under this title Theiszen gives the result of his examination of a number of doubtfully placed species. He classifies *Tympanopsis* among *Coronophoreæ*, a group very near *Sordarieæ*, and adds a new genus, *Euacanthe*, with a setose perithecium, to the group. Detailed descriptions of other genera and species are also given.
A. L. S.

Mycological Contributions.—Fr. von Höhnel (*Ber. Deutsch. Bot. Ges.*, 1917, **35**, 246–56) passes in review a considerable number of the smaller fungi, indicating mistakes that have been made generally of species placed in the wrong genera. He has established as new genera: *Discosphærina*, *Apioporthe*, *Pezizellaster*, *Lachnaster*, *Stereolachnea*, the last three on account of hair formation on margin or disc. Also *Calothyriella* and *Haplotheciella*, the latter based on *Dothedea Prostii*. Among Sphæropsideæ he describes *Septochroa* g.n. and *Phæophomopsis*, the latter based on *Phoma Hederæ*.

In a further paper (*Ann. Mycol.*, 1917, **15**, 293–303) von Höhnel criticizes a great many genera and species. He himself adds as new genera: *Hypodermellina*, with the associated *Rhabdostromellina*, *Europolella*, *Bifusella*, and *Eosphæria*. A. L. S.

Study of Fumagines.—F. W. Neger (*Flora*, 1917, N.F., **10**, 67–139, 31 figs.). The term "fumagine" is given to those fungi that live on the honey-dew of leaves. Such fungi are provided with a mucilaginous mycelium to protect them against drought. Artificial cultures were made of the fungi which are described. Numerous other

fungi are associated with them and appeared in the cultures. Neger enumerates as fumagines: *Dematium pullularis*, *Cladosporium herbarum*, *Hormiscium pinophilum*, with species of *Triposporium*, *Gyroceras*, *Torula*, *Helminthosporium*, *Sarcinomyces* and *Atichia*. A. L. S.

Mycological Fragments.—FR. VON HÖHNEL (*Ann. Mycol.*, 1918, **16**, 35–174.). The author continues his criticism of work done on Pyrenomycetes, with very full descriptive and explanatory notes. He makes a number of new species and of new genera: *Phyllocrea* (Hysteriaceæ), *Kriegerella* (Microthyriaceæ), *Didymellina* (near to *Didymella*), etc. Synoptic keys of the genera in several families are given. A. L. S.

Mycological Notes.—C. G. LLOYD (*Mycol. Notes, Cincinnati, Ohio*, 1919, 877–903, figs. 1497–1596). Lloyd gives descriptions and notes on a large series of fungi mostly from tropical or sub-tropical countries. He makes a new genus and species, *Bovistoides simplex*, collected by Miss Duthie, South Africa, distinguished by the capillitium, which consists of simple short wavy coloured threads with acute ends. Another fungus, which he describes as *Thelephora gelatinoidea* sp. n., may be, he thinks, a new genus, and suggests *Pseudothelephora* as a generic name. It has a gelatinous consistency, but the spores resemble those of *Thelephora*. A number of *Xylariæ* come under review. A. L. S.

Pimina parasitica, Grove.—A. LORRAIN SMITH (*Trans. Brit. Mycol. Soc.*, 1920, **6**, 295–6). The writer points out the close resemblance of *Urophiala mycophiala* described by Vuillemin to the above fungus. Vuillemin, on being consulted, agreed, but held that it belonged to a different species, and he also claimed that *Urophiala* should be the name of the genus, as *Pimina* was imperfectly described. A. L. S.

Preservation of Artificial Cultures of Moulds.—HARRY F. TAGG (*Trans. and Proc. Bot. Soc. Edinb.*, 1918–19, **27**, 335–7). The author describes various practical methods of preserving cultures on agar or gelatine either as herbarium material or as exhibition specimens. If the medium is not liquefied formalin may be used to kill and sterilize the preparation; if liquefaction has begun the process may be hastened by allowing hot water to enter below the medium and gradually to dissolve the gelatine. Further information is given as to mounting, etc. A. L. S.

Fungi of the Baslow Foray.—E. WAKEFIELD (*Trans. Brit. Mycol. Soc.*, 1920, **6**, 239–47). The itinerary for the several excursions from Baslow as a centre is given, with the special finds for the different localities, and finally a complete list of fungi collected during the autumn foray. Two species new to Britain, *Mycena dilatata* Fr. and *Botryotrichum piluliferum* Sacc. & March., were found along with other specimens. A. L. S.

Bacteria and Perithecial Development.—A. SARTORY (*C.R. Acad. Sci.*, 1918, **167**, 302–5). Sartory had already found that a bacterium

was necessary in the cultures to induce the sporulation of a yeast and the formation of perithecia in *Aspergillus*. He has repeated his experiments. He grew the *Aspergillus* on culture media with and without the addition of bacteria. When these were absent conidiophores and conidia were formed; perithecia very slowly and very rarely. With the bacteria present there was a ready and abundant formation of perithecia.

A. L. S.

Drain-blocking Fungus.—A. Lorrain Smith (*Trans. Brit. Mycol. Soc.*, 1920, **6**, 262–3). The writer describes the circumstances in which the fungus *Fomes ulmarius* was found blocking a sewer 30 ft. below ground in the City of London. There was no elm-tree in the vicinity, nor any evident nutriment for the fungus, but the gap in the pipes by which it had penetrated was evident. A. L. S.

Elementary Notes on the Morphology of Fungi.—A. H. Church (*Bot. Memoirs, Oxford, No.* 7, 1920, 1–29). Church states his aim in the opening sentence:—"Systematy includes the consideration of the Progression of Plant Life from first 'origins' to the condition of present vegetation," etc. He thus traces the origin and development of fungi from their algal ancestry in the sea, and, as polyphyletic, from a wide range of transmigrant algæ. All the groups from bacteria onwards are discussed. He closes with a consideration of the various types of symbiosis between fungi and other plants. A. L. S.

Notes and Additions to the Fungus Flora of Tasmania.—L. Rodway (*Papers and Proc. Roy. Soc. Tasmania*, 1920 (1919), 110–6). The author gives a series of notes on well-known fungi and diagnoses of several new species. We read that *Collybia butyracea* is common, chiefly amongst wattle-trees, that *Boletus badius* only appears under introduced pine-trees, etc. There is a new species of *Spragueola*, only one other species from America being known; also two new subterranean fungi, *Paurocotylis niveus* and *Sphærosoma tasmanica*. A. L. S.

Influence of Illuminating Gas on Bacteria and Fungi.—C. A. Ludwig (*Amer. Journ. Bot.*, 1918, **5**, 1–31). The paper deals with the toxicity of coal gas. In high concentration all bacterial or fungoid growth is checked or wholly stopped. Although different species are differently affected, on the whole the vigour of any strain is reduced by prolonged cultivation under the influence of the gas. The effect is not due to any one of the constituents, but is probably caused by the sum of the small effects of each plus the deficient oxygen content. The results, however, indicate that the gas incidentally present in any laboratory is quite harmless. A. L. S.

Upon the Visibility of Spore Dissemination in Fomes pinicola.—R. E. Stone (*Trans. Brit. Mycol. Soc.*, 1920, **6**, 293). The writer cites the experience of A. H. Buller, who had recorded seeing the discharge of spores from *Polyporus squamosus*; he saw the same kind of discharge from the under side of the fruit-body of *Fomes pinicola*; the spores streamed out and drifted away in the slight air currents.

A. L. S.

Higher Fungi in Relation to Human Pathology.—ALDO CASTELLANI (*Journ. Trop. Med. and Hyg.*, 1920, **23**, 101–10; 117–25, figs.). Castellani has chosen this as the subject of the Milroy Lectures. He sketches the history of our knowledge of the "higher fungi" as contrasted with bacteria, describes the fungi likely to be pathogenic, and gives an account of their chemical powers and the use that has been made of them to determine the presence of various substances in a solution. In the second lecture he describes cases of mycosis in (1) thrush, (2) broncho-mycoses, (3) tonsillo-mycoses, (4) certain mycoses of the nervous-system and organs of special sense, (5) certain mycoses of the uro-genital system. Thrush he finds to be caused by a fungus with a stout mycelium often showing arthrospores and numerous free oval or roundish budding yeast-like forms. He has isolated a great many different species and placed them in the genus *Monilia.* They vary chiefly in the effect ou sugars. Bronchial affections are caused by several different fungi:—*Nocardia*, *Monilia*, *Oidium*, *Hemispora*, *Aspergillus*, *Penicillium*, *Mucor* and *Sporotrichium*. The causative agents in other diseases are also given and the effects produced. The lectures are well illustrated. A. L. S.

Some Observations on Erysiphe Polygoni.—G. D. SEARLE (*Trans. Brit. Mycol. Soc.*, 1920, **6**, 275–9). *Erysiphe Polygoni* causes the swede mildew; this and various problems were attacked in the investigation. In field trials no kind of swede, turnip or rape out of seventy-seven tested was found to be immune to the disease. Biologic forms were proved to exist. As to overwintering it is suggested that the "most probable method of overwintering of the 'biologic form' of *Erysiphe Polygoni* on the cultivated *Brassicæ* is by means of subinfections on varieties of *B. oleracea* aided by persistent mycelium on varieties of *B. campestris*." The experiments are described in detail and the results set forth in six tables. A bibliography of the subject is appended.
A. L. S.

Iris Leaf-spot caused by Didymellina Iridis.—W. B. TISDALE (*Phytopathology*, 1920, **10**, 148–63, 6 figs.). The fungus is a severe disease of the broad-leaved Iris in Wisconsin and wherever the species is grown; other species are immune. The conidial stage is known as *Heterosporium gracile*; an abundant crop of conidia appear in spring and spread infection, penetrating the leaves by the stomata. Perithecia also develop in spring, but do not always produce asci. The fungus overwinters in the dead leaves. A. L. S.

Phyllosticta Blight of Snapdragon.—EDWINA M. SMILEY (*Phytopathology*, 1920, **10**, 232–48, 8 figs.). The disease gives an unsightly appearance to the host plants. On the leaves there appear brownish purple or dull brown spots usually near the top of the leaves. When the centre of the spot falls away a shot-hole effect is produced. Large brown spots are also formed on the stems. Pycnidia appear on the spots in more or less abundance, and may carry the plant over the winter season. The pathological effect of the disease on the tissues of the plant is described. Pure cultures were also made and the relations to different media studied. A. L. S.

"Brown Rot" Diseases of Fruit-trees, with special Reference to two Biologic Forms of Monilia cinerea. II.—H. Wormald (*Ann. Bot.*, 1920, **34**, 143–71, 2 pls.). The author has established the existence in Britain of two species of *Monilia*, viz. *M. fructigena*, the conidial stage of *Sclerotinia fructigena*, and *M. cinerea*. The former causes a fruit rot of apples, plums and cherries, and on apple-trees produces cankers by invading the branch through the fruit. *M. cinerea* causes "blossom wilt" and "canker disease" on apples; the same on plums, with, in addition, a "wither tip" of young shoots ; while on cherry-trees it gives rise to "fruit rot," "blossom wilt" and "twig disease." *M. cinerea* produces conidia from December onwards which are smaller than the summer forms. *M. fructigena* forms no conidia in winter. Various biological peculiarities are also described. A complete bibliography is appended. A. L. S.

Physiological Study of the Parasitism of Pythium debaryanum on the Potato Tuber.—L. A. Hawkins and R. B. Harvey (*Journ. Agric. Res.*, 1919, **18**, 275–97, 2 figs.). The authors experimented with a number of potatoes; they found that while some were very susceptible, others, such as the White McCormick, were resistant to the disease. They think it probable that the fungus penetrates the epidermis of the potato by puncture rather than by enzymes, and they explain the immunity of the McCormick tubers by the condition of its cell walls. The rate of growth of the fungus in the McCormick is also much slower. A. L. S.

Biology of Fomes applanatus.—J. H. White (*Trans. Roy. Can. Inst. Toronto*, 1919, 133–74, 6 pls.). The fungus attacks practically all deciduous trees and several conifers, causing great damage to timber. The author describes the basidiospores as: "Yellow papillate thick-walled chlamydospores within a thin hyaline wall." A. L. S.

Plant Sanitation in Fruit Plantations.—F. T. Brooks (*Trans. Brit. Mycol. Soc.*, 1920, **6**, 253–62). The author lays down certain principles that should be attended to if disease is to be eradicated from orchard, garden, field or forest. It is most important that no harbourage for the disease should be left. Discarded and dead branches should be removed ; dead or mummified fruits should be destroyed ; in the case of rusts the alternative hosts should be eliminated. Sanitation measures such as spraying, cultivation of the soil, etc., should be directed by experts with knowledge of the diseases and of the local conditions. The author is convinced that by careful control measures such baffling diseases as silver-leaf can be overcome; its presence is often due to great neglect. A. L. S.

Notes on some Diseases of Aspen.—Carl Hartley and Glen G. Hahn (*Phytopathology*, 1920, **10**, 141–7, 3 figs.). *Populus tremuloides*, a widely distributed American forest tree, is unusually subject to disease. The authors have investigated there and report :—Leaves are killed by *Sclerotium bifrons*, and rusted by *Melampsora albertensis* ; *Fomes igniarius* causes premature death in the stems, while other minute fungi attack injured portions. A. L. S.

Pink Disease of Citrus.—H. ATHERTON LEE and HARRY S. YATES (*Philippine Journ. Sci.*, 1919, **14**, 657–73, 7 pls., 2 figs.). This disease is caused by the fungus, *Corticium salmonicolor* Berk., which attacks the stem and branches of citrus trees. It has been well known as a disease of *Hevea*, and has been reported on *Citrus*, but not hitherto considered as a cause of serious trouble. The writers describe its appearance on the trees and their methods of treating it; they also give recommendations for the prevention of further spread. A. L. S.

Disease of Tomato and other Plants caused by a New Species of Phytophthora.—G. H. PETHYBRIDGE and H. A. LAFFERTY (*Sci. Proc. Roy. Dublin Soc.*, 1919, **15**, 487–505, 3 pls.). The root systems and lower portion of the stems are attacked by the fungus. It was successfully isolated and grown in artificial cultures in which the development of sexual organs took place. These conformed to the type of *Phytophthora infestans*, and the species has been named *P. cryptogea*. The fungus was also found causing a similar disease in *Petunia*, and may probably be the cause of disease in *Aster* and *Cheiranthus*. It was found by inoculation experiments to be pathogenic to potato and other plants. It is probable that the oospores of the fungus hibernate in the soil. Methods of control are outlined. A. L. S.

Botrytis Disease of Galanthus.—K. VON KEISSLER (*Zeitschr. Gärungsphys*, 1917, **6**, 18–27, 2 figs.; see also *Ann. Mycol.*, 1917, **15**, 160). *Botrytis galanthina* has caused considerable damage to cultivated plants of *Galanthus*. Lately the fungus has been found on wild plants; both the *Botrytis* stage and the sclerotium were found. A. L. S.

Leaf-disease of Tobacco in Roumania.—K. PREISSECKER (*Fachliche Mitteil. Oesterr. Tabakr. Wien*, 1916, Heft 1–15, 4 pls.; see also *Ann. Mycol.*, 1917, **15**, 161). Whitish or brownish spots on tobacco leaves were found to be caused by *Alternaria Brassicæ* var *tabaci*. A. L. S.

Studies with Macrosporium from Tomatoes.—J. ROSENBAUM (*Phytopathology*, 1920, **10**, 9–21, 2 pls., 1 fig.). From observation in the field, and from laboratory cultures the author distinguishes two diseases due to *Macrosporium*. "Nail-head" spots on fruit stem and leaves are caused by *Macrosporium Tomato* Cooke. Immature fruits are attacked in transit; fully ripe fruits seem to be immune. Another disease of stems and fruit is due to *M. Solani* E. and M., which grows chiefly on potato tubers. A. L. S.

Market Pathology of Vegetables.—K. K. LINK and MAX W. GARDNER (*Phytopathology*, 1919, **9**, 497–520). The rots dealt with in various vegetables and fruits are: (1) Slimy soft rot; all the bacterial soft rots attack cabbages, etc. (2) Watery soft rot, due to *Sclerotinia libertiana*; it is a prevalent vegetable rot. (3) *Rhizopus* rot; especially virulent on sweet potatoes. (4) Grey mould rot; includes rots due to *Botrytis*. An enumeration of different market produce is made with the rots to which they are subject. Other rots due to different fungi are also touched on. A. L. S.

Moulding of Snow-smothered Nursery Stock.—CARL HARTLEY, ROY G. PIERCE and GLENN G. HAHN (*Phytopathology*, 1919, **9**, 521–31). The authors state that evergreens smothered by tight packing or by snow covering are liable to injury from parasitic fungi attacking the leaves. *Botrytis cinerea* and a dark sterile mould unidentified are the most prevalent causes of trouble. The best way found to treat the disease is to sprinkle black soil on the snow early in spring to hasten the melting. Nurseries for raising Douglas fir should not be established where there are prolonged winter conditions. A. L. S.

Fungal Diseases of the Common Larch.—W. E. HILEY (*Oxford*, 1919, 204 pp., 73 figs.). The fungi dealt with in the book are in the following order, which is also the order of importance :—Canker due to *Dasyscypha calycina* ; heart-rot caused by *Fomes annosus* ; heart-rot less frequently caused by *Polyporus Schweinitzii*, *Poria vaporaria*, *Polyporus sulphurens* and *Torametes Pini* ; disease due to *Armillaria mellea* ; and finally leaf and seedling diseases, the former being attacked by *Sphærella laricina*, *Meria laricis*, *Hypodermella laricis*, *Melampsoridium betulinum*, *Melampsora tremulæ*, and the latter liable to suffer from damping off due to *Phytophthora omnivora* and *Fusoma parasiticum*. The list of diseases is, as observed by the author, rather depressing reading, but the fungi are not all equally virulent or equally common. Full descriptions are given of them all and of damage that results to the tissues from their presence. In a general summary at the end there is advice given as to the selection of soil for larch planting, so that the roots of the trees may be well aerated. The canker of the larch is possibly the most to be feared, as the fungus causing it is very wide spread ; but *Armillaria mellea* does also much harm and is equally abundant, and is not confined to larch. There is a good bibliography and a full index. A. L. S.

White Rot Disease of Onion Bulbs.—A. D. COTTON (*Journ. Agric.*, 1920, **26**, 1093–9, 3 figs.). The fungus causing the disease appears as a fine fluffy mycelium on the onions, which became attacked in the soil at the end of May or early in June, the visible symptoms of the disease being the wilting and yellowing of the foliage. At a further stage minute black sclerotia about the size of a poppy seed are formed in great numbers, and by August the plants are mostly killed. The sclerotia drop back into the soil where they pass the winter. In spring the sclerotium germinates directly, forming hyphæ which infect new onion plants. The name *Sclerotium cepivorum* was given by Berkley to the fungus in 1841, and has been retained as it never shows any *Sclerotinia* stage. No success has followed the use of soil fungicides, and the best way of combating the disease is to starve out the fungus by changing the crop for a number of years—eight or ten may not be too long. A. L. S.

Leaflets on Plant Diseases.—MINISTRY OF AGRICULTURE AND FISHERIES (Publications Branch, 3 St. James's Square, London, S.W.1). A series of these leaflets have recently been revised and re-written, and may be had free of charge from the Publications Branch. They

include No. 87, "The Die-back (*Cytospora*) Disease of Fruit-trees," that attacks the branches; No. 120, "Peach Leaf-curl" (*Exoascus deformans*); No. 133, "Powdery Mildew of the Vine" (*Uncinula necator*), a leaf disease; No. 164, "Potato Leaf-curl," the origin of which is obscure; No. 195, "American Gooseberry Mildew" (*Sphærotheca Mors-uvæ*), a mildew which attacks leaves and branches; No. 242, "Stripe Disease of Tomatoes," due to a bacillus; No. 271, "Clover Stem-rot" (*Sclerotinia trifoliorum*); No. 302, "Silver Leaf in Fruit-trees," generally caused by *Stereum purpureum*; and No. 345, "The White-rot Disease of Onion Bulbs," distinguished by the white mycelium on the bulbs. The last-mentioned is a new publication. All of the leaflets are illustrated, and with the description of the disease certain instructions are given how best to combat it. A. L. S.

Lichens.

Short History of Lichenology.—Charles C. Plitt (*Bryologist*, 1919, **22**, 77–85). An account is given of lichens in botanical literature from the earliest references onwards. The advance of knowledge concerning these plants is also outlined with reference to their structure and to the development of the fructifications. The author gives quotations from various lichenologists who have held strong views on the nature and autonomy of lichens. A. Lorrain Smith.

Schedulæ of Lichenes Ticinenses Exsic.—Const. Mereschkovsky (*Ann. Conserv. Jard. Bot. Genève*, 1919, **21**, 145–216). The author publishes here descriptions and notes on some 120 species. They have been collected and issued to complete another collection which he had undertaken, but of which much of the material had to be abandoned in Kazan. A. L. S.

Lichens from Transcaucasia.—J. Steiner (*Ann. Mycol.*, 1919, **17**, 1–32). A large series of lichens sent by Woronoff to Steiner have been determined. There are a number of new species. The greater number are common European species. Steiner remarks on the number of Central European forms, and also notes the abundance of *Lecanoræ* rather than *Lecideæ*, with the great lack of *Verrucariæ*. He considers that certain lichens may be found in a narrow belt all round the world. A. L. S.

Supplemental Report on the Lichens of Epping Forest.—R. Paulson and Percy G. Thompson (*Essex Naturalist*, 1919, **19**, 27–30). The authors have added about twenty species, varieties or forms to the lists of present-day lichens in Epping Forest published by them in 1911 and 1913. The total record of lichens from the locality is now 127. A. L. S.

Lichens of the Baslow Foray.—A. Lorrain Smith (*Trans. Brit. Mycol. Soc.*, 1920, **6**, 252). A short account of lichens found at or near Baslow. The district is affected by the smoke of Sheffield, and the lichen vegetation is not abundant. A. L. S.

Additions to Lichen Distribution in North America.—Bruce Fink (*Mycologia*, 1919, **11**, 296–307). The lichens enumerated were mostly collected in Western America by the writer in such widely-separated regions as the islands of Puget Sound, British Columbia, and Laggan, Alberta. Other collectors sent contributions from various western areas. A bare list with locality and habitat appended.

A. L. S.

Contribution to the Lichenographia of Thüringen.—G. Lettau (*Hedwigia*, 1919, **61**, 97–175). Lists of lichens from Thüringia, the total lichen flora for the region numbering, according to the author, about 594. Many descriptive and biological notes are added. In an appendix there is a list of fungi parasitic on lichens. A. L. S.

Mycetozoa.

Mycetozoa from Cornwall.—G. Lister (*Journ. Bot.*, 1920, **58**, 127–30). The account of Cornwall Mycetozoa was partly prepared by Dr. A. Adams, who died last autumn. He was a keen student of the group, and experimented with living specimens. Several of the species recorded are new to England. Other collectors who contributed notes are G. H. Fox and J. M. Coon. Eighty-two species and four varieties are included, with localities of the rarer forms. A. Lorrain Smith.

Mycetozoa found during the Baslow Foray.—G. Lister (*Trans. Brit. Mycol. Soc.*, 1920, **6**, 248–52). During two previous forays at Baslow forty-four species of Mycetozoa were found; the number on the last occasion was forty-five, and fifteen of these are new to Derbyshire.

A. L. S.

MICROSCOPY.

B. Technique.

Cellular Changes in Cartilage Grafts.—J. A. Murray (*Sci. Rep. Imp. Cancer Research Fund*, 1919, **6**, 71). Slow degenerative changes take place in the cells of cartilage grafts. Accompanying the deposition of fat-globules, which is probably only an exaggeration of what occurs in undisturbed cartilage, there are nuclear changes regarded by Murray as amitotic. In a human autologous graft irregular achromatic spindles and attraction spheres were found and figured. The paper describes the methods found useful by the author for the study of cartilage grafts. As they are of more general application they are given here in greater detail :—

Gelatin Slides for Frozen or Gum Sections.—Clean slides are coated with a film of 1 p.c. gelatin in distilled water. The film must be as thin as is compatible with the formation of a continuous layer, spread with a glass rod or slide (like a blood film). The slides are put aside to dry and kept till required. To fix sections on slides, immerse the slide in water containing the sections in a flat dish. Arrange in position with a glass rod, withdraw the slide with the sections on it, and drain off the superfluous water. Lower a wet cigarette-paper over the sections, and dry by pressing on firmly a thick layer of absorbent paper (blotting or filter). Strip off the cigarette-paper and place the slide in a tube, with a wad of cotton soaked in commercial formalin at the bottom. In two to four minutes the gelatin film will be sufficiently hardened to keep the sections in position. Complete the fixation by immersing the slide in a bottle of 10 p.c. formol in 0·8 p.c. salt solution. Staining can now be carried out without fear of the sections coming adrift, unless hot mineral acid solutions are used for more than ten minutes.

Salkind's Lead-gum Imbedding Method (*C.R. Soc. Biol.*, 1916, **79**, 811).—An aqueous solution of gum arabic, treated with lead acetate, is transformed into a *gel* on exposure to vapour of ammonia. On addition of acetic acid it returns to the *sol* condition. This is the basis of the imbedding method, which is as follows :—1. Dissolve cherry-gum (white), 1 part (by wt.), in aq. dest., 2 parts (by wt.). 2. Filter (this is usually very slow, and I usually use more water. The yellow and brown samples of gum practically will not filter). 3. Add to the clear solution one-third of its volume of liq. plumbi subacetatis fort., containing 5 p.c. acetic acid. 4. The tissues to be cut are soaked in the clear solution so prepared, usually 12 hours for each millimetre in thickness. They may be kept in it indefinitely. 5. To prepare for cutting, allow the water to evaporate at room temperature till the liquid is of the consistency of thick collodion solution. 6. Arrange the piece in a drop of thickened gum on a wooden block and expose to ammonia

vapour. The mass solidifies at once, and is ready to cut in $\frac{1}{4}$ to $\frac{1}{2}$ hour. After 10 hours the mass becomes brittle and cuts badly. 7. Cut on the sliding microtome with an oblique knife wetted with 1 p.c. salt solution in distilled water. Transfer the sections to a dish of this salt solution, in which they spread out. After an hour they become opaque white and crumble, therefore fix on the slide by the method described above before this happens. 8. Remove the lead-gum by soaking the slides, with sections attached, in 5 p.c. acetic acid for 5–15 minutes and washing in running water. Stain and mount as desired.

Hollande's Chlorocarmin Staining Method.—Place 5 c.cm. pure hydrochloric acid in a porcelain dish. Add little by little 14 grm. powdered carmin, stirring constantly to make a homogeneous doughy mass. Allow to digest for 24 hours. Add 250 c.cm. distilled water, bring to the boil, and keep boiling for $\frac{1}{2}$ hour. Filter; make up to 180 c.cm. with distilled water, and then add enough 75 p.c. alcohol to make a total volume of 200 c.cm. Stain sections or pieces in this solution for 2–24 hours. Rinse in distilled water or 30 p.c. alcohol. Immerse in 3 p.c. iron-alum solution, in which the sections become black and are then slowly decolorized. When differentiation is complete, rinse in 1 p.c. pyridin and wash under the tap for 10–15 minutes. Counterstain and mount as desired.

METALLOGRAPHY, Etc.

Differential Crystallization in a Cast Steel Runner.—F. B. Foley (*The Iron Age*, Dec. 18, 1919). The author discusses a remarkable specimen (some 2 in. in diameter) in which the microstructure varies from normal "ingot" structure, through "Widmannstättian" and back to "ingot" again. Photomicrographs taken from the outside towards the centre of the runner are appended.

The Effect of Initial Temperature upon the Physical Properties of Steel.—J. H. Andrew, J. E. Rippon, C. P. Miller and A. Wragg (Iron and Steel Institute Meeting, May, 1920). In this research the effect of variation in initial temperature upon the position of the resulting transformation points in certain Ni, Cr and Ni–Cr steels has been determined.

The Structure of some Chromium Steels.—J. H. G. Monypenny (Iron and Steel Institute Meeting, May, 1920). It appears that the properties of austenitic chromium steels are of great theoretical interest, since they show that martensite is the first stage in the decomposition of austenite.

Note on the Structural Constitution, Hardening and Tempering of High-Speed Steel containing Chromium and Tungsten.—K. Honda and T. Murakami (Iron and Steel Institute Meeting, May, 1920). The tempering of high-speed steel takes place in two steps, at approximately 400° C. and above 700° C.

The Distribution of Phosphorus in Steel between the Points Ac1 and Ac3.—J. H. WHITELEY (Iron and Steel Institute Meeting, May, 1920). Details are given of methods for etching phosphoretic steels for microscopical analysis, and further work has been undertaken on the subject of "ghost-lines."

Some Defects in Electro-deposited Iron.—W. E. HUGHES (Iron and Steel Institute Meeting, May, 1920). The author concludes that electrolytic iron is prone to a number of defects that make it unsuitable for engineering purposes. The view that its hardness is due to the presence of hydrogen is called in question.

Silica Brick from the Roof of an Open-hearth Furnace.—J. E. STEAD (*Trans. Ceramic Soc.*, 1918–19, **18**, 389–98). A silica brick from a Middlesbrough furnace had been reduced in size from 12 in. × 6 in. × 3 in. to 12 in. × $2\frac{7}{8}$ in. × $2\frac{3}{8}$ in. The results of microscopical examination of this brick are given.

The Microstructure of Zinc Retorts.—A. SCOTT (*Trans. Ceramic Soc.*, 1918–19, **18**, 512–15). Two types of zinc silicate are present. The spinel crystals forming one of the chief constituents of used zinc retorts are identical with gahnite, $ZnAl_2O_4$.

Effect of Nitrogen on Steel.—GEORGE F. COMSTOCK and W. E. RUDER (*Chemical and Metallurgical Engineering*, March 3, 1920, **22**, No. 9). A résumé of the important literature on amount of nitrogen in various classes of steels, its method of occurrence and effect on physical properties, together with some recent experiments on its action during heat treatment.

Nature of the Defects revealed by the Deep Etching of Transversely-fissured Rails.—HENRY S. RAWDON (*Chemical and Metallurgical Engineering*, March 17, 1920, **22**, No. 11). Microscopic studies which show that "gashes" developed by deep etching of polished surfaces correspond to tightly closed intracrystalline cracks; they may be discovered by dipping a magnetized specimen into a suspension of fine iron dust.

Genesis of Ferrite.—FEDERICO GIOLITTO (*Chemical and Metallurgical Engineering*, April 21, 1920, **22**, No. 16). Contrary to commonly accepted ideas, the ferrite in hypo-eutectoid steels is not extruded as a shell to the outside of austentic kernels, but exists as an aggregation of crystals essentially discontinuous at the low-carbon nuclei of solid solution grains.

Copper and Magnetite in Copper Smelter Slags.—CHARLES G. MAIER and G. D. VAN ARSDALE (*Chemical and Metallurgical Engineering*, June 16, 1920, **22**, Nos. 24–5). Chemical and microscopic examination of a series of representative slags, showing how copper losses occur, the relation of magnetite to copper loss, the behaviour of converter slags in reverberatory furnaces, and suggestions for reducing copper slag losses.

PROCEEDINGS OF THE SOCIETY.

AN ORDINARY MEETING

OF THE SOCIETY WAS HELD AT No. 20 HANOVER SQUARE, W., ON WEDNESDAY, MARCH 17TH, 1920, PROFESSOR JOHN EYRE, PRESIDENT, IN THE CHAIR.

The Minutes of the preceding Meeting were read, confirmed, and signed by the President.

The nomination papers were read of four Candidates for Fellowship.

New Fellows.—The following were elected Ordinary Fellows of the Society :—

Mr. George Frederick Bates, B.A., B.Sc.
Mr. Joseph Graham, B.Sc.
Mr. Kennett Knight Hallowes, M.A., F.G.S., A.R.S.M., A.Inst.M.M.
Mr. William Jabez Ireland,
Captain Ralph G. A. Thorne, B.A.
Miss Evelyn J. Welsford, M.B.E., F.L.S.

Donations were reported from :—

Mr. P. E. Radley, F.Z.S.—
"Catoptricae et Dioptricae Sphaericae Elementa" (Davide Gregorio, 1695).
"Dioptrische Untersuchungen" (C. F. Gauss, 1841).

Messrs. Methuen & Co., Ltd.—
"Iron Bacteria" (Dr. Ellis).

On the motion of the **President**, hearty votes of thanks were accorded to the donors.

Mr. E. J. Sheppard exhibited a slide—mitosis in hyacinth root-tips—showing marked differentiation in the staining of the chromosomes.

Dr. Drew exhibited slides showing the Golgi apparatus in the cells of the onion root and in the epididymus of the rat.

On the motion of the **President**, hearty votes of thanks were accorded to Mr. Sheppard and Dr. Drew.

Dr. C. Da Fano gave a demonstration of the Golgi Internal Apparatus in Nervous and other Tissues. (Details of this demonstration will be found on pages 157–61 of the present issue of the Journal.)

Dr. Murray congratulated Dr. Da Fano. For himself the particular interest was that although they all had a prejudice against metallic impregnation methods, they must recognize that, by the application of the new methods, the Golgi apparatus presented a characteristic appearance in each of the tissues. Although the appearances differed according to the staining method, it was very suggestive that they had there a real constituent of the cell. What its function was or what it was for it was difficult to determine.

Mr. E. J. Sheppard said that in Professor Schaefer's "Essentials of Histology" was shown an enlarged figure of an animal cell in which were seen the radiating structures, and these were described as trophoplasm or canula which might be demonstrated or not according to the method of fixation. The canula could not be seen unless the preparation was suitably fixed. He had many times seen the canula in various structures in the unfixed and the lightly-fixed preparations, and he was not sure that he had not also seen them by the aid of dark-ground illumination. He was not an upholder of the precipitate method as applied to silver impregnations. If the canals did exist it was easy to precipitate upon them and show the structure. If they existed there was a very wonderful field for research. At present he looked upon them with some scepticism. He warmly congratulated Dr. Da Fano upon his beautiful exhibits.

Dr. Gatenby thanked the Society for the interest it had shown in the discussions on the Golgi apparatus and mitosis. He had attended a good many meetings, and had met with a deal of scepticism. He was glad to hear Mr. Sheppard now admit that there might be such a thing as the Golgi apparatus. It had been seen *intra vitam* in tissue cultures and in the ovotestis and ganglion cells of the snail. He had lately been using Dr. Da Fano's method, and some of his best results had been obtained with this cobalt nitrate method.

Dr. Drew drew attention to two exhibits that were being shown. They were from an onion and a rat. The chief interest lay in the fact that the specimens had been fixed by Dr. Da Fano's method, cut with a freezing microtome, and stained with iron-hæmatoxylin.

The President said that the Society was much indebted to Dr. Da Fano and to the other observers who had taken part in the discussion, which had brought out many important points. He moved from the Chair that the best thanks of the Meeting be accorded to Dr. Da Fano.

This was carried by acclamation.

Mr. T. E. Wallis read a paper on "The Lycopodium Method of Quantitative Microscopy," which was illustrated by lantern slides and exhibits. The paper is printed in the present issue of the Journal (see pages 169–78).

A discussion followed, in which **Mr. Barnard**, **Mr. Sheppard**, and

Mr. Blood took part, after which a hearty vote of thanks was accorded to Mr. Wallis for his paper.

A vote of thanks was accorded to Messrs. Hawksley and Sons for the loan of fifteen microscopes.

The President announced that the next Meeting of the Biological Section would be held on April 7, when there would be a further discussion on Dr. Tierney's communication, "The Bacterial Flora of Water."

The business proceedings then terminated.

AN ORDINARY MEETING

OF THE SOCIETY WAS HELD AT NO. 20 HANOVER SQUARE, W., ON WEDNESDAY, APRIL 21ST, 1920, MR. A. N. DISNEY, VICE-PRESIDENT, IN THE CHAIR.

The Minutes of the preceding Meeting were read, confirmed, and signed by the Chairman.

The Nomination Papers were read of six Candidates for Fellowship.

New Fellows.—The following were elected Ordinary Fellows of the Society :—

Mr. Corrado Da Fano, M.D., L.D.
Mr. T. D. Tuton Hall.
Mr. Morris Charles Lamb, F.I.C.
Mr. Duncan James Reid, M.B., C.M.

The following papers were read in title, and it was announced that they would be published in the Journal :—

Mr. B. L. Bhatia, M.Sc., F.Z.S.—
"Notes on Fresh-water Ciliate Protozoa of India."

Mr. Aubrey H. Drew, D.Sc.—
"A Preliminary Note on the Golgi Apparatus in Plants."

Mr. J. Brontë Gatenby, B.A., B.Sc., D. Phil., and Mr. J. H. Woodger, B.Sc.—
"On the Relationship between the Formation of Yolk and the Mitochondria and the Golgi Apparatus during Oögenesis."

The business proceedings then terminated.

On the same evening in the Lecture Hall was held a General Discussion on

THE MECHANICAL DESIGN AND OPTICS OF THE MICROSCOPE.

Professor John Eyre, M.D., M.S., etc., President of the Royal Microscopical Society, opened the proceedings with a short Address.

Mr. J. E. Barnard gave a "General Survey," which was followed by abstracts of the following papers on the

MECHANICAL DESIGN OF THE MICROSCOPE.

(*a*) *General.*
Professor F. J. Cheshire, C.B.E., "The Mechanical Design of Microscopes."
Mr. Conrad Beck, C.B.E., "The Standard Microscope."
Mr. F. W. Watson Baker, "Progress in Microscopy from a Manufacturer's Point of View."
Mr. Powell Swift, "A New Microscope."

Sir Robert Hadfield, Bart., D.Sc., F.R.S., President of the Faraday Society, then took the Chair during the reading of the abstracts of the following papers :—

(*b*) *Metallurgical.*
Dr. W. Rosenhain, F.R.S., "The Metallurgical Microscope."
Professor Cecil H. Desch, D.Sc., "The Construction and Design of Metallurgical Microscopes."
Mr. E. F. Law, "The Microscope in Metallurgical Research."
Mr. H. M. Sayers, "Illumination in Micro-metallography."

(*c*) *Petrological.*
Dr. J. W. Evans, F.R.S., "The Requirements of a Petrological Microscope."

A discussion followed on the foregoing papers.

Mr. Robert S. Whipple, President of the Optical Society, then took the Chair during the reading of abstracts of the following papers on the

OPTICS OF THE MICROSCOPE.

Professor A. E. Conrady, "Microscopical Optics."
Dr. H. Hartridge, M.A., "An Accurate Method of Objective Testing."
Mr. H. S. Ryland, "The Manufacture and Testing of Microscope Objectives."
Mr. F. Twyman, "Interferometric Methods."

A discussion followed on the foregoing papers.

A full report of the proceedings will be published in connexion with the report of the Symposium held on January 14, 1920.

AN ORDINARY MEETING

OF THE SOCIETY WAS HELD AT 20 HANOVER SQUARE, W., ON WEDNESDAY, MAY 19TH, 1920, PROFESSOR JOHN EYRE, PRESIDENT, IN THE CHAIR.

The Minutes of the preceding Meeting were read, confirmed, and signed by the President.

The nomination papers were read of three candidates for Fellowship.

New Fellows.—The following were elected Ordinary Fellows of the Society :—

Mr. Harold Brumwell.
Mr. Reginald Henry Marchment.
Le Vicomte de Sibour, F.Z.S.
Mr. Charles F. Sonntag, M.D., Ch.B.
Mr. Donald Sutherland, M.A.
Mr. William Turner.

Donations were reported from :—

Mr. G. T. Harris—
A Collection of Slides of Bryophyta.
Dr. E. J. Spitta—
"Microscopy" (New Edition).
Messrs. W. Wesley and Son—
"Common Diatoms" (T. K. Mellor).

On the motion of the **President**, hearty votes of thanks were accorded to the donors.

Pond-Life Exhibition.—The **President** then called upon Mr. Scourfield to make some observations on the Annual Exhibition of Microscopic Pond-Life which had been arranged by Fellows of the Society and Members of the Quekett Microscopical Club.

Mr. Scourfield said that it had been his privilege, in connexion with several previous Pond-Life exhibitions, to call attention to some of the special problems which could be studied only by observation of the living organisms, such problems, for instance, as the movements of pond-life organisms and the correlation of their structure to particular modes of life. He proposed that evening to refer briefly to yet another matter which could only be satisfactorily approached in the same way, namely, the colour of microscopic aquatic organisms. Mr. Scourfield then alluded to some of the commoner colours presented by such organisms,

directing special attention to the animal types of a green colour. In most cases these green animals were found to owe their characteristic colour to the presence, just under the ectosarc or ectoderm, of symbiotic algæ usually known as zoochlorellæ. Such cases occurred among the Rhizopoda in some species of *Difflugia*, etc.; among the Heliozoa in one species of *Raphidiophrys*; among the Ciliata in species of *Stentor*, *Paramæcium*, *Vorticella*, *Ophrydium*, etc.; among the Hydrozoa in *Hydra viridis*, *H. igneus*, etc.; and among the Turbellaria in *Dalyellia viridis*, etc. It was evident that a number of interesting questions arose out of this peculiar association of animals and plants, the solution of which would almost certainly yield results of fundamental biological importance.

Closely connected with the colour of organisms was the mode of its distribution over the surface of the body. When this was not uniform it usually gave rise to some kind of pattern, and this was an important but very obscure subject upon which a good deal of light could undoubtedly be thrown by a study of small aquatic creatures in which colour patterns occurred in their simplest forms.

Proceeding to refer in detail to the actual exhibits, Mr. Scourfield made special mention of the abnormal specimens of *Simocephalus vetulus*, shown by Mr. Cannon, which had been produced by feeding upon a species of *Chlamydomonas*. These were similar to those described by Prof. Agar in an important paper in the Transactions of the Royal Society on the inheritance of acquired characters in certain species of Entomostraca, etc.

On the motion of the **President**, a hearty vote of thanks was accorded to the Members of the Quekett Microscopical Club, and to the Fellows of the Royal Microscopical Society who had kindly exhibited specimens, and to Mr. Scourfield for his remarks.

The President announced that the next Meeting of the Biological Section would be held on June 2, when Mr. Scourfield would read a communication on "Zoochlorellæ."

The business proceedings then terminated.

List of Pond-Life exhibits—

Mr. A. J. Bowtell . .	*Vorticella* sp.
Mr. H. G. Cannon .	*Simocephalus vetulus*, showing abnormality, similar to that described by Prof. Agar in Trans. Roy. Soc., produced by feeding on a species of *Chlamydomonas*.
Mr. F. W. Chipps . .	*Lophopus crystallinus*, also *Batrachospermum*.
Mr. H. Goullee . .	Larvæ of *Tanypus* just emerging, also young newt.
Mr. C. E. Heath . .	*Lophopus crystallinus*.

Mr. T. H. Hiscott . .	*Acanthocystis turfacea.*
Mr. J. T. Holder . .	*Closterium* sp., showing movement of granules in terminal vesicles.
Mr. H. E. Hurrell . .	*Lophopus crystallinus.*
Mr. J. J. Jackson . .	*Euglena* sp., *Chlamydomas* sp., etc.
Mr. H. J. Lawrence .	*Micrasterias truncata.*
Dr. J. Rudd Leeson .	*Spirillum*, *Euglena*, etc.
Mr. W. J. Magenis. .	*Bacillus coli*, etc.
Mr. E. R. Martin . .	*Hydra fusca.*
Mr. E. K. Maxwell. .	*Œcistes stygis.*
Mr. J. C. Myles . .	*Stephanoceros eichhornii.*
Mr. E. R. Newmarch .	*Plumatella repens* and *Melicerta ringens.*
Mr. R. Paulson . .	*Spirogyra longata* and *Ulothrix variabilis.*
Mr. F. J. W. Plaskitt .	*Euglena spirogyra.*
Mr. J. Richardson . .	*Cothurnia imberbis.*
Mr. W. Russell . .	*Melicerta ringens.*
Mr. D. J. Scourfield .	*Hydra fusca*, showing brown bodies which give the colour to the animal.
Mr. R. S. W. Sears. .	*Amœba proteus*, also *Hydra viridis* and *Volvox globator.*
Mr. C. J. H. Sidwell .	*Hydra viridis*, showing nematocysts and the symbiotic algal cells, which give the green colour to the animal.
Mr. A. E. Smith . .	Larva of beetle *Acilius sulcatus.*
Mr. B. J. Thomas . .	*Stephanoceros eichhornii.*
Mr. W. R. Traviss . .	*Anacharis*, showing circulation.
Mr. G. W. Watts . .	*Closterium* sp.
Mr. H. C. Whitfield .	*Closterium* sp.
Mr. S. R. Wycherley .	*Floscularia campanulata* and *Philodina aculeata.*

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TRANSACTIONS OF THE SOCIETY.

VII.—*Notes on Fresh-water Ciliate Protozoa of India.*

By B. L. Bhatia, M.Sc., F.Z.S., F.R.M.S., Assistant Professor of Zoology, Government College, Lahore.

(*Read April* 21, 1920.)

Very little work has been done so far on the fresh-water Protozoan fauna of India. Up to 1889, the year of publication of Bütschli's work on Protozoa (*6*),* practically the only record of fresh-water forms was based on the work of H. J. Carter, who studied these forms in Bombay towards the middle of the last century, and published a number of papers (*7, 8, 9, 10*). In 1862 J. Mitchell contributed a short note from Madras (*17*). From 1869 to this date nobody appears to have seriously taken up the study of fresh-water Ciliates in India, and I am unable to find any record of these interesting organisms from India, except for a paper by Annandale (*4*) and another by Ghose (*13*).

In a previous paper (*5*) the writer recorded a number of species of Ciliates occurring in fresh water collected from ditches, ponds, etc., in and about Lahore, which are enumerated below for ready reference :—

Holophyra indica Bhatia.
Urotricha globosa Schewiakoff.
Enchelys arcuata Clap. & L.
Lacrymaria vermicularis Ehrbg.
Coleps hirtus O. F. Müll.
Didinium nasutum Stein.
Loxophyllum fasciola (Ehrbg.) Cl. & L., subsp. *punjabensis* Bhatia.
Nassula stromphii Ehrbg.
Trichoda pura Ehrbg.
Colpoda cucullus Ehrbg.
Paramecium caudatum Ehrbg.
Spirostomum ambiguum Ehrbg.

* The italic figures within brackets refer to the Bibliography at end of the paper.

The study of the fresh-water Ciliates of this locality has been continued, and the forms met with are recorded. Very little work having been previously done on the fresh-water Protozoan fauna of India, most of the forms encountered are being recorded for the first time from any part of India. The best thanks of the writer are due to Lieut.-Colonel J. Stephenson, D.Sc., I.M.S., Principal and Professor of Zoology, Government College, Lahore, for the guidance and encouragement he has always received, and for great assistance in obtaining a number of books and periodicals dealing with Protozoa, but for which the work could not have been undertaken.

Lahore is situated in the plains of the Punjab (India, latitude 31° 34′ N., longitude 74° 21′ E., height above sea-level 706 feet), and experiences extremes of temperature conditions in its hot and cold seasons. The principal rainfall of the year takes place in the months of July and August, and this is followed by a period of drought, in which most temporary collections of water dry up. The majority of the pools examined were only temporary collections of water after rains, some being only a few centimetres deep. Samples of water from some of the artificial ponds, such as the tanks in the Shalamar Gardens and the duck-ponds in the Zoo, have also been examined. Protozoan life seems most abundant at Lahore in the summer season, i.e. from May to September. The specimens obtained were mostly studied in the living condition either under a small cover glass or as hanging-drop preparations, and as a rule a preliminary examination of a sample of water was made, with the aid of a centrifuge, on the same day that the water was collected. For slowing the movements of rapidly moving forms, the mucilage obtained by soaking *Ispaghul* seeds (seeds of *Plantago ovata*) was found to give very satisfactory results. This mucilage can be readily obtained in varying degrees of consistency, and has the further advantage of being perfectly transparent. It can be added directly on the slide to the drop of water containing the Ciliates, or the seeds are spread at the bottom of the tube in a layer about 1–2 cm. high, and the culture containing the Ciliates poured on to them to the height of 8–10 cm., when in a day or two by the diffusion of the mucilage into the culture a proper consistency is obtained.

Of the reagents commonly used, I have employed: (1) for fixing, concentrated solution of corrosive sublimate, hot or cold; sublimate alcohol (concentrated watery solution of corrosive, 2 parts, 90 p.c. alcohol, 1 part); or vapour of 4 p.c. osmic acid solution—all of which gave good results; (2) for rendering cilia distinct, a 1 p.c. solution of alum; and (3) for staining, principally acetic-methyl green, washing it out with water to which a few drops of liquor ammoniæ have been added.

The forms met with are recorded below, with brief notes on

them. Regarding measurements of size, the terms very small, small, of medium size, large, and very large are used for dimensions as defined by Schewiakoff. The writer has recorded his own measurements only where they differ markedly from those usually given.

HOLOTRICHA.

Family HOLOPHRYINA Perty.

Genus *Spathidium* Dujard.

Spathidium spathula O. F. Müll, var. *moniliforme* var. nov.

Found in large numbers in stagnant water from a drain (September). The animals may be referred to *Spathidium spathula* O. F. Müll., inasmuch as the body is flask-shaped, flexible, though not very contractile, the anterior end narrower than the middle of the body, obliquely truncate, and occupied almost completely by the narrow and elongated slit-like mouth. The margins of the oral portion are padded. The general surface of the body appears to be striate. The cytoplasm is granular, the anterior portion of the body being somewhat clearer. The contractile vacuole is single and situated near the posterior end. The ciliation is uniform, except that the cilia round the anterior end are slightly longer. The movements of the animal are slow, the anterior part of the body occasionally bending slightly.

The form met with however differed from the type in its very much smaller size and the character of the nucleus. The animals measured 105μ by 20μ, instead of the usual size, which is mentioned as $180–240\mu$. The macronucleus consists of a long chain of small beads, and is bent upon itself. In the generic characters given in Bütschli (*6*) the nucleus is said to be round to elongated and rosary-shaped, but in the figure of *S. spathula* is shown as consisting of three large beads only. E. André (*3*) has described under the name of *S. spathula* var. *plurinucleata* a form containing a large number of separate rounded nuclei. The present form differs from the latter in that these small nuclei are not regularly scattered but are parts of an elongated rosary, which is bent upon itself. Hence the form may be said to belong to a new variety, for which the name var. *moniliforme* is proposed.

Genus *Prorodon* Ehrbg.

Prorodon teres Ehrbg.

Specimens of this form were found in great abundance in a collection of rain-water which had been standing for less than a

week on the roadside near the Chauburji grounds in August. Every drop contained several specimens. The animals were 63–84 μ by 45 μ in size, and contained yellow or brown algæ. The form however differed from the one figured in Lang (*15*) in certain important respects. The macronucleus, which is large and sphæroidal, is situated in the anterior half of the body, and is carried about in the granular endoplasm. When stained with acetic methyl green it is found to be of the granular type, and a small rounded micronucleus is placed on its surface. The mouth is anterior and terminal, but the pharynx does not extend as far back as there figured. The animals were examined after slowing their movements by the mucilage obtained from *Ispaghul* seeds (seeds of *Plantago ovata*), and the pharynx studied in a dilated condition. It was found to be 12 μ in length, and measured 9 μ across at its anterior end, becoming somewhat narrower posteriorly. The fascicle of rods in the pharynx was distinct, and eight rods could be counted in the surface presented to view. The cilia on either side of the mouth were slightly longer than over the rest of the body. The contractile vacuole is single and situated near the posterior end of the body, though in one specimen, which was about to disintegrate, two subsidiary ones were also seen situated on one side of it.

Family AMPHILEPTINA Bütschli.

Genus *Loxophyllum* Duj.

Loxophyllum fasciola Cl. & Lachm.

Specimens belonging to this typical form were found in large numbers in September in water from a drain. Body small, 63 μ in length, greatest width 31 μ.

Genus *Loxodes* (Ehrbg.) Cl. & Lachm.

Loxodes rostrum (O.F.M.) Ehrbg. (= *Pelicida rostrum* Duj.).

Specimens referable to this species were found in water from a pond in the Lawrence Gardens (August). The usual size recorded for the species by Eyferth (*12*) is 450–580 μ, but the specimens found in Lahore were very much smaller. One specimen measured 126 μ by 44 μ, another 150 μ by 63 μ. This agrees fairly closely with the minimum size as recorded in Kent (*14*) ($\frac{1}{150}$ in.), or Pritchard (*17*) ($\frac{1}{144}$ in.). Ciliation uniform, marginal cilia short, fine, and close set, the cilia bordering the adoral groove being somewhat larger. The mouth is situated in the concave border of the proboscis, which measured 32 μ in one specimen and 42 μ in the other. Body flexible, but persistent in form, with the anterior extremity curved slightly to the left; posterior end bluntly pointed

and also curving slightly inwards in the same direction. The endoplasm is granular and vacuolated, and numerous chloroplasts are scattered in it, the colour of the part of the body free from them being greyish. Macronuclei are numerous, spherical, of the vesicular type, and irregularly distributed in the posterior three-fourths of the body, but the connecting cord-like filament or funiculus could not be observed. The micronuclei also were not made out.

There was a single contractile vacuole situated about the middle of the body, and a row of numerous very much smaller vesiculæ arranged along the left border which were non-contractile.

Family Chilifera Bütschli.

Genus *Glaucoma* Ehrbg.

Glaucoma pyriformis Stein. (?)

The animals, which I have referred with some hesitation to this species, were found in August in water from a pond in Lawrence Gardens, and measured 60 μ by 30 μ. The form of the body is somewhat pyriform, ciliation is uniform though very fine; cilia over the general surface were distinctly visible with $\frac{1}{12}$ in. oil immersion and No. 6 compensating ocular, those along the margin being equally fine and situated rather apart from one another. The mouth is situated about 9 μ from the anterior end, and the oral fossa is provided with an undulating membrane arising from both margins, with a finger-shaped projection protruding from the middle. The macronucleus, which is of the granular type, is ovoidal and situated about the middle, the small micronucleus lying close to its posterior edge. The contractile vacuole is near the middle.

Genus *Colpidium* Stein.

Colpidium colpoda Stein.

In infusions of dry leaves.

Family Paramecina Duj.

Genus *Paramecium* O.F.M.

Paramecium bursaria Ehrbg.

In pond water. Size 84 μ by 40 μ to 95 μ by 42 μ. Anterior end obliquely truncate; contractile vacuoles two, spherical in some specimens and stellate in others. Macronucleus kidney-shaped. Mostly with Zoochlorellæ.

HETEROTRICHA.

Family STENTORINA Stein.

Genus *Stentor* Oken.

Stentor sp.

Specimens belonging to *Stentor* sp. were once found in a pond near Chhota Ravi river, but the specimens were not identified.

Family HALTERINA Cl. & Lachm.

Genus *Halteria* Duj.

Halteria grandinella O. F. Müll.

Found in water in a pond in Lawrence Gardens in the month of August. The specimens exhibited the usual movements so characteristic of the species. Form somewhat spherical, with a small triangular depression at the anterior end, with a small number (six or seven) of stiff cilia at the anterior end, and a few slender bristles from the central region of the body. Macronucleus kidney-shaped. Contractile vacuole in the anterior half of the body. Size about 25 μ.

HYPOTRICHA.

Family PLEUROTRICHINA Bütschli.

Genus *Pleurotricha* Stein.

Pleurotricha grandis Stein.

In infusion of dry leaves. Size 84 μ by 42 μ.

Family ASPIDISCINA Ehrbg.

Genus *Aspidisca* Ehrbg.

Aspidisca costata Duj.

In large numbers in water from drain near a water-tap in the laboratory compound. Body very small, possessing six deep canals on the dorsal surface.

Aspidisca lynceus Ehrbg.

Body very small, length about 24 μ. In pond water from Shalamar Gardens, among *Spirogyra* filaments, in August. Form oval, posterior part broader, posterior end truncated, anterior end pointed, with the peristomial cleft under its overlap. Five posterior styles ; frontal styles distributed partly over the ventral surface of the body, four on the central portion of the ventral surface, and three near the anterior end.

Dorsal surface smooth and not furrowed. Contractile vacuole near the posterior end. Nucleus horse-shoe shaped. Locomotion characteristic, swimming round and round, now from left to right, now from right to left, sometimes stopping, and jumping or creeping forward.

PERITRICHA.

Family Vorticellina Bütschli.

Genus *Scyphidia* Duj.

Scyphidia fromentelii S.K. (?).

The specimens, which I have referred to this species with some hesitation, were found in August attached to the carapace of *Daphnia*, in pond water from Shalamar Gardens. Body small, 52 μ by 25μ, form elongated, posterior end thinner and provided with a rounded sucking cup. In a specimen detached from the host, this posterior end was seen to contract independently as in sucking. Body transversely wrinkled. Peristomial margin thickened and reversible. Contractile vacuole anterior, near the middle of the body. The form differed however from the description of the type as recorded in Kent (*14*) in that the body was transversely wrinkled, and the posterior extremity was not seen to be longitudinally plicate.

Genus *Vorticella* Ehrbg.

Vorticella campanula Ehrbg.

In water from a pond in the Lawrence Gardens. On leaves of *Lemna*, mostly on leaves which are dried up and brownish. October. Social. Size 63 μ to 73 μ being common.

With characters of the type.

Vorticella citrina Ehrbg.

Very abundant in an infusion of dry leaves (August). Body broadly campanulate, not narrowed behind the anterior end. Length of the body, including the basal cone-like projection, 26 μ in one specimen (somewhat contracted), and 50 μ in another specimen. Length of the stalk about three to five times the length of the body.

Genus *Carchesium* Ehrbg.

Carchesium epistylidis Cl. & Lachm.

Numerous colonies on the gills, legs and tail bristles of Ephemerid larvæ in pond water from Shalamar Gardens (August), each colony consisting of a few (two to four) individuals only. Individual zooids separately contractile, the thread in the stalk being interrupted at each bifurcation. Stalk four to five times the length of the body, smooth, and in contracting the portion of the stalk near the animal thrown into a spiral. Some stalks end in two zooids, the stalk just bifurcating near the tip, one portion containing the thread and the other not. Individual zooids about 32 μ in length; anterior end slightly less wide than the middle of the body; peristomial margin thickened, slightly reversible. Contractile vacuole situated about the middle of the body. Nucleus slightly curved, somewhat kidney-shaped. Contracted zooid pyriform in shape, cuticle smooth.

The form encountered differed however from the type in lacking the articulate character of the stalk.

Genus *Epistylis* Ehrbg.

Epistylis plicatilis Ehrbg.

Forming a whitish tuft on shells of snail (probably *Limnæus*) in pond water in Shalamar Gardens (August). Long dichotomously branching colonies; individuals independently contractile, with no thread running in the stalk. The secondary branches of the stalk showed longitudinal striations at the attachment of the zooid, but are otherwise granular and somewhat feathery in appearance. Length of the expanded zooids is 84 μ to 126 μ. Peristomial margin dilatable; ciliary disc capable of considerable projection when the animal is in a fully expanded condition. When contracted there is an anterior projection, and the posterior half of the body shows distinct transverse pleating, which is characteristic of the species.

Epistylis articulata From.

Growing abundantly on all sides on a small spirally coiled Gastropod shell (probably *Planorbis*), on which it forms a white fluffy mass; found in pond water in Shalamar Gardens. Colonies erect, height of colony about 0·6 mm. Pedicle dichotomous, sparingly branched, striate longitudinally, articulate at one or two intervals between each bifurcation, in which respect it differs from *E. plicatilis.* Body form as in that species, but two zooids at termination of each terminal stalk.

Kent (*14*), in a note to the description of this species, observes as follows:—"In shape the animalcules of this species appear to closely resemble those of *E. plicatilis,* and it is a question whether the chief point of difference cited by de Fromentel, that of the articulation at distant intervals of the pedicle, is sufficient to distinguish them, more especially as, in the last-named form, Stein has remarked that old specimens are similarly jointed. No mention is made as to the form assumed by the zooids when in a state of contraction, which would have been useful in the settlement of this supposed identity, nor as to whether the species forms large or small colonies."

I am able to throw some light on this disputed point, having observed the zooids in the contracted condition. The form assumed by the contracted zooids is globular, the posterior part showing transverse furrows as in *E. plicatilis.* The size of the colony, which is considerably smaller than that of *E. plicatilis,* and the fact that two zooids are perched at the termination of each stalk, along with articulate character of the stalk, which is constant in one and a rare feature in the other, will serve to distinguish between the two species.

SUCTORIA.

Family Podophryidæ Bütschli.

Genus *Sphærophrya* Cl. & Lachm.

Sphærophrya pusilla Cl. & Lachm.

Body very small, found parasitic in *Paramecium caudatum* A specimen containing four young individuals was encountered in October. Two individuals, provided with knobbed tentacles all round, escaped under observation and began to swim freely.

TABLE OF INDIAN SPECIES OF CILIATA.

Species	Recorded from India by other writers	Found and recorded by the Author
Holophrya lateralis S.K.	+	−
,, *indica* Bhatia	−	+
,, *bengalensis* Ghosh.	+	−
,, *annandalei* Ghosh.	+	−
Urotricha globosa Schew.	−	+
Enchelys arcuata Cl. & Lachm.	−	+
Spathidium spathula var. *moniliforme* var. nov.	−	+
Prorodon teres Ehrbg.	−	+
Lacrymaria vermicularis Ehrbg. sp.	−	+
Coleps hirtus O. F. Müll.	+	+
Didinium nasutum Stein.	−	+
Mesodinium pulex Cl. & Lachm.	+	−
Loxophyllum fasciola Ehrbg. sp.	+	+
,, ,, sub. sp. *punjabensis* Bhatia	−	+
Loxodes rostrum Ehrbg.	−	+
Nassula sp.	+	−
,, *stromphii* Ehrbg. sp.	−	+
Chilodon cucullulus O. F. Müll. sp.	+	−
Glaucoma pyriformis Stein. (?)	−	+
Trichoda pura Ehrbg.	−	+
Frontonia leucas Ehrbg.	+	−
Ophryoglena sp. (= *Otostoma carteri* S.K.)	+	−
Colpidium colpoda Stein.	−	+
Paramecium aurelia O. F. Müll.	+	−
,, *caudatum* Ehrbg.	−	+
,, *bursaria* Ehrbg.	−	+
Plagiopyla (?) *carteri* S.K.	+	−
Spirostomum ambiguum Ehrbg. var. *minor*	−	+
Climacostomum virens Ehrbg.	+	−
Stentor sp.	+	+
Folliculina ampulla O. F. Müll.	+	−
Halteria grandinella O. F. Müll.	−	+
Pleurotricha grandis Stein.	−	+
Oxytricha sp.	+	−
Euplotes charon O. F. Müll.	+	−
Aspidisca costata Duj.	−	+
,, *lynceus* Ehrbg.	−	+
Scyphidia fromentelii S.K. (?)	−	+
Vorticella microstoma Ehrbg.	+	−
,, *patellina* O. F. Müll.	+	−
,, *convallaria* L.	+	−
,, *campanula* Ehrbg.	−	+
,, *citrina* Ehrbg.	−	+
Carchesium epistylidis Cl. & Lachm.	−	+
,, *polypinum* Ehrbg.	+	−
Epistylis galea Ehrbg.	+	−
,, *plicatilis* Ehrbg.	−	+
,, *articulata* From.	−	+
Cothurnia sp. (= *Pyxicola carteri* S.K.)	+	−
Vaginicola sp.	+	−
Syhærophrya sp.	+	−
,, *pusilla* Cl. & Lachm.	−	+
Podophrya fixa Ehrbg.	+	−
Tokophrya quadripartita Cl. & Lachm.	+	−
Acineta tuberosa Ehrbg.	+	−

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VIII.—*The Problem of Synapsis.*

By Lancelot Hogben, M.A., B.Sc., Lecturer in Zoology, Imperial College of Science and Technology.

(*Read June* 16, 1920.)

The attention which has been directed of late years by Duesberg, Cajal, Weigl, Guillermond, Gatenby and others upon the behaviour of the intracellular inclusions in the germ cycle of animals and plants has again called in question the Weismannian doctrine relating to the genetic significance of the nucleus. In attempting to correlate the phenomena of cell anatomy with our knowledge of the hereditary mechanism there are two propositions which may be stated at the outset as a basis of agreement. First, that in all cases of biparental reproduction of which we have any knowledge both parents contribute equally to the constitution of the zygote; secondly, that the only data in genetics which permit any legitimate inference as to the behaviour of the substantial basis of inherited characters during the germ cycle are those derived from the pursuit of Mendelian experiment. The first must be borne in mind in approaching any theories which attempt to distinguish between "specific" and "generic" characters in the process of hereditary transmission. The demonstration of paternal characters in Echinoid generic hybrids by MacBride and Debaisieux, as also the observations of Baltzer, Doncaster and others on chromosome elimination, leave no justification for assuming that there is any difference between the paternal and maternal moieties contributed to the zygote, or, as Jenkinson believed, between the rôle of cytoplasm and nucleus respectively, in relation to the specific and generic characteristics of the organism. At the same time we must dismiss every sort of speculation upon heredity based on a consideration of cell structure unsupported by experimental fact. When, therefore, authors like Mottier declare that they only claim the transmission of non-Mendelian characters by the chondriosomes, etc., it is hardly possible to treat such hypotheses with serious consideration. There may be a mode of inheritance which on analysis yields no evidence of segregation or factorial integrity; but whether there is or not, at present nothing is known of such a mechanism as could provide a foundation for correlating the behaviour of the cell elements with it. It must therefore be conceded that at present genetic cytology has to build upon the data of Mendelism; and it may be safely said that such considerations

exclude both mitochondria and chondrioplasts (Golgi rods) from the exercise of a direct part in hereditary transmission. The unequal distribution of these elements during cytokinesis and their inconstant numerical relations (cf. Wilson on *Opisthacanthus*); their elimination either wholly or partly from the male gamete either during spermateleosis (Gatenby and Montgomery), or before fertilization (Lillie); and finally, their failure to provide any evidence of segregation in gametogenesis (cf. especially Gatenby on *Limax*), demonstrate (1) that the complex of one-cell generation is not integrated in such a way as to be individually representative of that of another; (2) that in many cases at least the mitochondrial or chondrioplast organization of the zygote has no continuity with that of the male parent. The relation of the maternal and paternal cytoplasmic inclusions provides no means of effecting alternating inheritance.

Thus to-day the importance of the nucleus in inheritance has been emphasized rather than diminished by the attention which improved technique has directed to other parts of the cell. The immediate problem of genetic cytology therefore concerns the manner in which the nucleus itself functions in the process; and naturally, the theory of synapsis, or the conjugation of chromosomes derived from alternate parents preparatory to this segregation in the maturation divisions, occupies a position of central importance in the discussion. Considerations in favour of the recognition of chromosomes as units in the hereditary process have been drawn from cytological studies in relation to sex determination, mutation, and generic hybridization; and since these have been admirably epitomized by Gates and Doncaster (Q.J.M.S., 1914), they do not call for comment in this place. The most fruitful basis however for a discussion of the chromosome hypothesis concerns, whether, in the behaviour of the chromosomes in the germ cycle, we are actually witnessing the mechanism of alternating heredity in operation. This problem has become an increasingly technical one, the issues of which have not been sufficiently criticized.

In treating of the growth of the modern doctrine of Synapsis, it is convenient to accept as a starting point Sutton's observations (1902) on the chromosome groups of *Brachystola*, published shortly after the rediscovery of Mendel's laws by Correns, Tschermak and De Vries; for it cannot be too insistently stated that the whole theory rests primarily upon the fact of chromosomal heteromorphism rather than the behaviour of the nucleus in the meiotic phase. To illustrate the bearing of heteromorphism among chromosomes on the theory of gametic segregation a more convenient example than *Brachystola* itself is furnished by Nakahara's recent work on the Stonefly, Perla (1919). The spermatogonial complex here consists of ten chromosomes, which may be arranged according to

size and shape as follows: a and a' are rod-like and equal; two pairs, β and β', γ and γ', are V-shaped and equal; one pair, δ and δ', are minute and spherical; while the fifth pair is unequal, x and y. Reduction takes place in the formation of the sperms, and the second spermatocyte has the constitution a or $a' +$, β or $\beta' +$, γ or $\gamma' +$, δ or $\delta' +$, x or y. Assuming that, as in all the closely allied insects, x is equally paired in the female, it follows that the gamete has one representative of each pair of chromosomes in the gametogonial cells; and if it is legitimate to assume that the chromosomes of the latter correspond individually to those of the zygote, it is clear, since the zygote is the product of the union of two gametes, that the process of "reduction" involves the resolution of chromosome pairs into their maternal and paternal components. The debatable implication of this argument is the assumption that the chromosomes of one cell generation individually correspond to those of another. As is well known, the chromatin organization of an ordinary resting nucleus exists in a reticulate condition, so that it is not possible to settle by immediate inspection whether the chromosomes are temporary and inconstant aggregates of chromatin particles, or whether on the other hand to decide in favour of a definite structural continuity of the former as opposed to an interpretation of a more remote character. Upon this decision the elaborate body of doctrine embodied in "the chromosome hypothesis" logically rests.

The considerations in favour of the view that each chromosome of the prophase corresponds structurally to a similarly constituted chromosome in the preceding telophase may be summarized as follows:—(1) Actual continuity occurs in certain plants; "prochromosomes" were first observed by Schwarz (1892) and Zacharias (1895); they have been recently studied by Overton, Rosenberg and Stout (1913). (2) The transition of the chromosomes of the telophase into the reticulate condition, and the emergence of the prophase from this state studied by Overton in *Podophyllum*, Digby (1919) in *Osmunda;* also Boveri's work on the relation of the chromosomes to the orientation of the reticulum in the curiously lobed nuclei of *Ascaris*, seem to indicate clearly that the reticulum is itself a complex of "unit reticula," corresponding to the chromosomes themselves. (3) The numerical relations exhibited in the behaviour of the chromosomes in mitosis always fulfil the expectations that would be anticipated on the assumption of persistent individuality not only in normal reproduction but also in cases of polyspermy (Boveri), and of hybrids from parents with complexes that are numerically unlike (Federley). (4) The character of the complex when it exhibits heteromorphism is only such as could be expected if the chromosomes maintained their individuality intact from one generation to another. This is very arresting in the case of hybrids (Federley, Baltzer) of parents whose chromosomes are

distinguishable in size and shape, but the most important data are derived by the study of multiple chromosmes in the Orthoptera. Referring to the existence of a "hexad" in the maturation division of a species with the accessory united to an ordinary chromosome in the premeiotic mitosis, McClung comments thus: "One of the elements possesses a distinctive character not shared by the others—it has an individual and more or less independent movement which takes place at only one time in all the history of the organism. Up to this one point it is distributed in mitosis like the other chromosomes; . . . so much of the chromatin substance possesses distinctive characters. Are these the consequence of separate unity, or is there some specific nature of the material? The history of the hexad multiple answers this question, for although joined to another element the same characteristic behaviour occurs." Summing up the evidence, it may be said that in certain cases persistent individuality is demonstrable directly; in other cases the reticulum appears to be definitely organized with respect to the mitotic complex; while in mitosis generally the facts in all cases coincide with those which would be anticipated from the assumption that the loss of chromosomal individuality during interkinesis is only apparent. Furthermore, the persistent individuality of chromosomes is a sound working hypothesis; it permits of verifiable predictions which could not be legitimately inferred without its aid—as, for instance, the existence of octads and hexads in the heterotype complex of forms with multiple chromosomes (see McClung, op. cit). To accept it as such does not imply a denial of the possibility that some mechanism may be discovered which could manœuvre the chromatin granules so as to produce the effects observed without preserving this continuity and integrity of structure. Since, however, Fick, Della Valle, Meves, Granata, and its critics generally have failed to reveal such a mechanism, the theory of persistent individuality affords at present the most satisfactory interpretation of the nucleus.

The earlier exponents of the doctrine under consideration were content to gather evidence in favour of the reality of synapsis, relegating the means by which the conjugation of homologous chromosomes is effected to a position of secondary importance. The study of partial linkages compels enquiry into the latter problem increasingly to-day. It is not enough to interpret the phenomena of independent segregation and coupling of different pairs in terms of localization in identical or distinct bivalents; some mechanism must be found to account for "crossing over" if the chromosome hypothesis is to develop further, and such a mechanism Prof. Morgan's school claims to find in the twisting of bivalent threads. It is not possible to criticize here the issues generally raised by the "chiasmotype" theory; it is sufficient to say that such an attempt to provide an interpretation of partial

linkage in Mendelian inheritance is exceedingly ambitious in view of the widespread disagreement concerning the genesis of the heterotype chromosomes. And it is a surprising fact that many chromosome workers appear still to treat the mode of synapsis as a matter of little concern. McClung declines to offer any view as to the genesis of the bivalents in the Orthoptera from their component halves; yet it is evident that the whole theory of synapsis stands or falls with its consistency with the events of the maturation prophases.

As regards the events which occur in animals two views are commonly maintained to-day. Janssens, the Schreiners, Von Winiwarter, Agar, Wenrich, Wilson find in general that the initial event is the parallel conjugation in pairs of chromatin ("leptotene") filaments equivalent in number to the chromosomes of the preceding telophase; this is followed by the longitudinal splitting of the reduced "pachytene" threads. The heterotype chromosomes ("tetrads") are formed by the drawing out of the double threads of the previous stage ("diplotene") along the line of cleavage so that the transverse constriction of the tetrad corresponds to the longitudinal split in the diplotene filament. Assuming that this cleavage separates the original conjugants, the heterotype mitosis is reductional, the homotype equational (for the autosomes). Unfortunately, to be certain that actual segregation of the bivalent components occurs, it is necessary to be able to trace the double character of the bivalent at every stage of the process.

The view stated above has been criticized by Goldschmidt and his pupils, Arnold and certain earlier workers on the Orthoptera (Sutton, Davis). According to these workers the heterotype chromosome is found to be developed by the union of the looped diplotene thread by its free ends so that the heterotype division constricts the diplotene thread transversely, while the longitudinal cleavage is interpreted as a precocious preparation for the homotype mitosis. According to the exponents of this hypothesis synapsis, if it occurs, must involve the end to end union (telosynapsis or metasyndesis) of the conjugants rather than the parallel conjugation (parasynapsis) described by the American school. In accordance with this view they are unable to find any stage at which the full diploid number of elements is present in the meiotic stage—from the first the chromatin is present as the reduced number of longitudinally split loops or threads. They employ the old conception of the "continuous spireme" to explain how the adherence of chromosomes in pairs end to end may have come about; but no cytologist claims to have actually witnessed a telosynaptic union in animals. Recently Nakahara (1919) has provided striking evidence for this view in the case of the Perlidæ; but the great difficulty raised is the similarity of the diplotene stage in both telosynaptic and parasynaptic accounts of the meiotic phase.

Since the two views are mutually exclusive, and since the phenomena are in many points essentially similar in all cases, it is difficult to accept as a compromise the existence of both modes of union. In attempting an evaluation of both sides of the controversy it must be remembered that the diplotene threads often pass through a complicated series of changes in the process of tranforming into the heterotype chromosomes, so that satisfactory evidence of the relation of the transverse cleavage of the latter to the longitudinal split in the former can only be obtained if the history of individual chromosomes is studied as Wenrich (1917) has done. Secondly, it must be conceded that the parasynaptic accounts have been based on some of the most favourable material for study (Batrachoseps and Lepidosiren). Finally, in a large number of cases where early investigators described a telosynaptic transformation of the heterotype chromosome, and denied the existence of a diploid leptotene stage, subsequent workers have disagreed with their conclusions. This applies not only to the work of Goldschmidt, Arnold and others on Flatworms, which has been denied by Gelei and later workers, but to all the earlier work on the Orthoptera. In regard to the latter it is only necessary to mention the names of Morse, Mohr, Steevens, Vejdovsky, Gérard, Robertson, Wenrich, Otte, all of whom have adopted the theory of parallel conjugation; and the work of Metz and others showing the lateral association in pairs of the chromosomes in the somatic complex of Diptera has increasingly influenced cytologists in favour of parasynapsis.

In opposition to both schools Duesberg has attacked the whole theory of synapsis from a study of the meiotic phase itself. Duesberg's own work on the spermatogenesis of the Rat has been very destructively criticized by Allen; but as his general thesis has certain points in common with views held by botanical cytologists it merits (brief) comment. Briefly, he holds that the events of the meiotic phase are not essentially different from those of a normal prophase. Now a comparison with a normal prophase must be based upon similarity in number, size and shape or disposition of the chromatin elements. As regards number Duesberg is content to neglect the witness of reliable workers who claim that the full diploid number of leptotene threads is present at the inception of the meiotic phase. With respect to the form of the chromatic elements there is obviously no basis of similarity between the leptotene threads and the flocculent prochromosome of a normal prophase; while the polar orientation of the meiotic nucleus is a phenomenon which Duesberg is content to dismiss from serious consideration on the basis of his own incomplete observations on the rat. It is true to say that the majority of competent cytologists are compelled to recognize in opposition to this view that the meiotic phase in the nucleus is an event *sui generis.*

Some cytologists have attempted to draw a too detailed comparison between the phenomena of the meiotic phase in animals and plants, consequently the issue has been very much complicated, for reasons that will appear. As early as 1905 Farmer and Moore formulated a theory of meiotic phase in plants and animals based upon a comparison of a series of types (*Osmunda, Periplaneta, Lilium*) and advocating a telosynaptic interpretation. The principal animal type, *Penplaneta,* was selected, unfortunately, owing to the peculiar difficulties of Orthopteran spermatogenesis; and subsequent work has made it clear that the Blattids in reality conform to the theory of parallel conjugation. Since then the terms "telosynapsis" and "parasynapsis" have come into use in botanical cytology in a sense altogether different from that in which they are employed in zoology. Of the two contractions of the chromatin threadwork in the premeiotic phase of plants the telosynaptic theory identifies the second, the parasynaptic theory the first, as the point at which synapsis of homologous chromosomes is effected. Grégoire has compared the first contraction stage of plants to the bouquet stage in animals (1906–11), thus aggravating the confusion in existing terminology. Now, Miss Digby (1919) has shown recently that in *Osmunda* the archesporial chromosomes undergo cleavage in the telophase, and that the fusion witnessed in the first contraction stage of the meiotic nucleus is in reality the reassociation of half-chromosomes split in anticipation of a division which is arrested. In view of the fact that wherever the leptotene threads in animals can be definitely counted their number corresponds to the telophasic chromosomes, and also the possibility of tracing them back to the latter in a number of cases (e.g. Wilson in Hemiptera), it may be stated without hesitancy that the data embodied in the interpretation of the first contraction phase of plants by Farmer, Digby, Gates and others have no bearing on any stage which occurs normally in animals.

Turning now to the bearing of the study of the meiotic phase on the general theory of synapsis derived from a consideration of the heteromorphism of chromosome complexes, the principal questions that arise are, first, whether there is actual evidence that chromatin elements conjugate; second, whether such elements are chromosomes *sensu stricto*; lastly, whether the conjugating elements are subsequently disjoined by a reduction-division. As regards the first, all those who advocate parasynapsis in animals are agreed; concerning the second, a few authors (e.g. Wilson) claim to have established continuity between the telephase chromosomes and the conjugating filaments; while with respect to the last, the fusion of the conjugating elements in parasynapsis is usually so complete that it is almost impossible to be certain that they do not lose their individuality, as believed by Vejdovsky and Bonnevie. It will thus be seen that while the chromosome hypothesis has

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proved a great incentive to research—particularly in the problem of sex—its major premise, the reality of synapsis, is in no way firmly established; further knowledge of the relation of chromosomes to the organization of the resting-nuclei and a specialized study of individual heterotype chromosomes constitute, therefore, two of the most imperative needs of cytological theory to-day.

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IX.—*Further Notes on the Oögenesis and Fertilization of Grantia compressa.**

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One Plate.

Introduction.

So far as at present known the sponge is the only animal in which the male element does not itself penetrate the egg directly, but first enters another cell which is thereby induced to carry the sperm to the expectant ripe oöcyte.

Precocious fertilization, such as occurs in *Saccocirrus* or *Otomesostoma* (*5*),† is a very peculiar process, but no carrier cell intervenes between oögonium and spermatozoon, and so the process does not introduce a third cell as in the sponge.

In this paper I have described a stage hitherto missing from my previous description (*3*), and I have taken the opportunity to examine further the "chromidia" formation found by Jörgensen (*7*) and Dendy (*2*).

The First Stages of Fertilization in Grantia compressa.

In a previous paper I have described the peculiar fertilization in a sponge, in which the spermatozoon enters a collar cell and is thereby carried to the ripe oöcyte. All the spermatozoa found in collar cells were oval structures containing a bun-shaped reticulate nucleus and a similarly shaped mitochondrial middle-piece. From some stages of spermatogenesis found by me in *Grantia* it was known that the spermatozoon (spermatid) was provided with a flagellum. It was concluded that the ovoid spermatozoa found in the collar cells were somewhat changed in shape, a result due to their presence in another cell, and that very probably the

* The materials used in this research were purchased by a Government Grant of the Royal Society.

† The italic figures within brackets refer to the Bibliography at the end of the paper.

spermatozoon of *Grantia* was filiform and flagellate like the majority of metazoon sperms.

This year more material was sent from Plymouth by Dr. Allen, and one missing stage was found; this stage nearly completes the story of the fertilization of *Grantia compressa*, and confirms the views expressed in the previous paper (*3*).

In Pl. V, fig. 2, is drawn a part of an oöcyte of *Grantia*, and on the left a row of choanocytes lining the flagellated cavity. At NNS is the sperm-carrying collar cell whose nucleus has become altered under the influence of the sperm at MP; the spermatozoon is ovoid in shape, and at this period still lies within the cytoplasm of the collar cell.

Earlier stages than this were not found in the material prepared last year, but in fig. 1 is a much earlier stage. The coarsely dotted area above represents the ectoplasm of the *Grantia* oöcyte (E in Pl. V, fig. 2), and three collar cells are represented; the middle one contains at N, MP the head of middle-piece of a spermatozoon. The latter is still elongated, and it seems sufficiently clear that the sperm here beginning to alter in shape was filiform. Such a stage closely resembles what one finds in a typical metazoon fertilization just after the filiform sperm has entered the egg.

EXPLANATION OF PLATE V.

Lettering.—BM., basal membrane; CN., collar cell (choanocyte) nucleus; E., ectoplasm; EM., egg membrane; EN., endoplasm; FL., flagellum; G., mitochondrial (in some cases yolk) granule; H., halo of dense cytoplasm around nucleus; MP., sperm nucleus; N., nucleolus; NU., nucleus; NNS., nucleus of the sperm-carrying collar cell; X., extruded nucleolar material still lightly staining.

All figures on Plate V, excepting 1 and 2, drawn from Champy-Kull material stained after sectioning by Benda's alizarin and crystal violet method. Figs. 1 and 2 are drawn from ordinary Champy-Kull material.

The scale of figures is near fig. 10.

All Grantia compressa.

Fig. 1.—Three collar cells, showing the spermatozoon embedded in one; the head of the sperm is at N, the middle-piece at MP. The dotted area on the right is the ectoplasm of the oöcyte. The relationship of these parts can be seen by examining fig. 2, where E is the ectoplasm.

Fig. 2.—Later stage, showing at NNS the changed nucleus (NNS) of the collar cell which contains the spermatozoon (MP). This changed collar cell has sunk below its fellows in the germinal epithelium; on the right is a part of a ripe oöcyte, at E and EN are the ectoplasm and endoplasm respectively of the oöcyte, and at NU a part of its nucleus.

Fig. 3.—Collar cell. Arrow points to inhalent chamber.

Fig. 4.—Progerminative collar cell, about to become an oögonium.

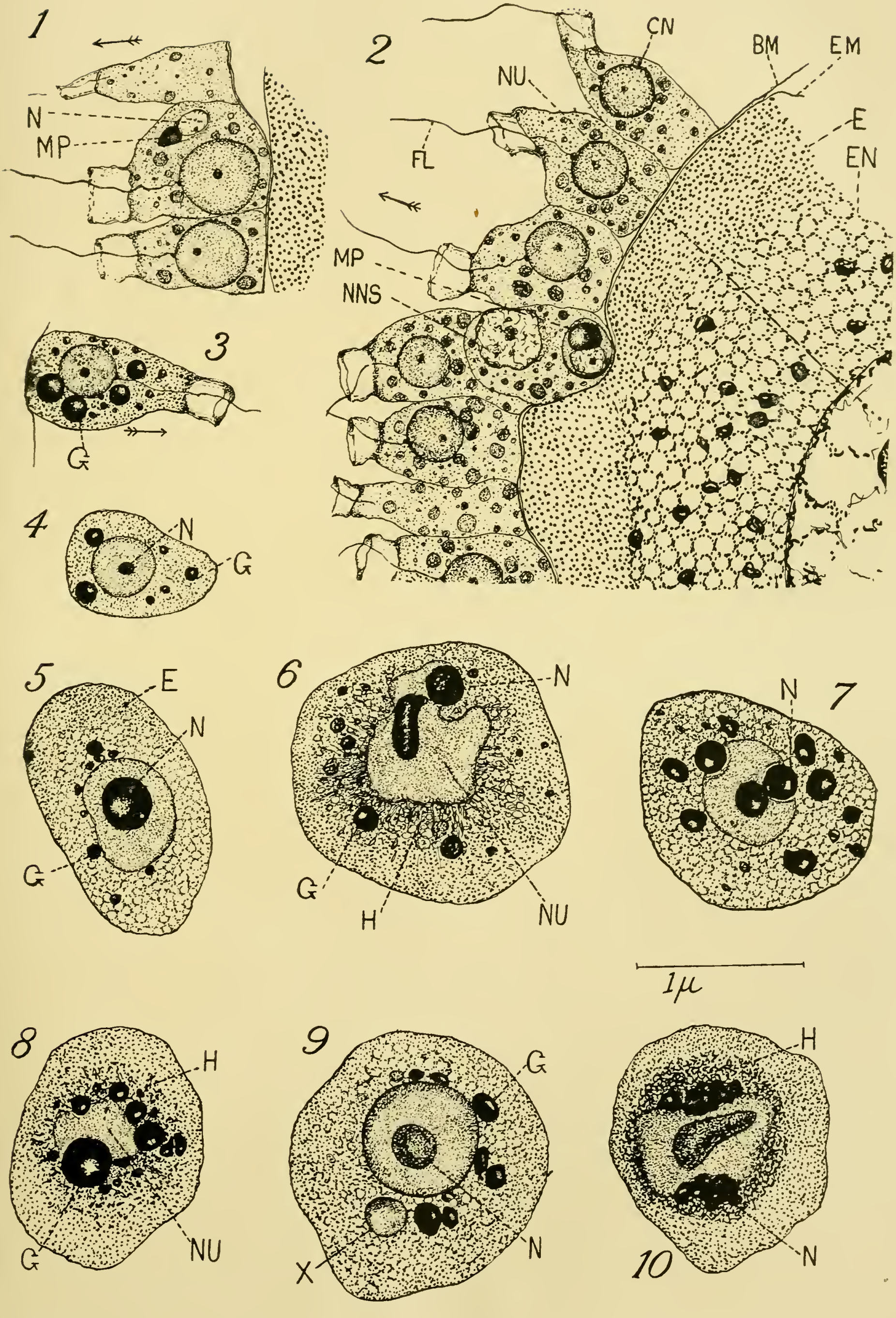
Fig. 5.—Later stage of above, showing enlargement of nucleolus.

Fig. 6.—Oögonium at the stage of extrusion of nucleolar fragments (N). A halo of thickened cytoplasm indicates perinuclear activity (H).

Figs. 7, 8.—Stages in extrusion of nucleolar (plastin) fragments.

Fig. 9.—Nucleus reformed after its collapse (e.g. in fig. 8).

Fig. 10.—Another form of extrusion of nucleolar fragments.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New Interpretations of the Nucleolar Extrusion in the Oögenesis of Grantia compressa.

Dendy (*2*) has described a peculiar process in the oögenesis of *Grantia*, whereby pieces of the nucleolus are squeezed out into the cytoplasm. In his figures 40–44 of Plate XXV Dendy has given figures illustrating the process.

I believe that such a peculiar occurrence is rare in the oögenesis of animals, and for a time I had some doubt as to the correctness of the description previously given (*2*).

Further material has been collected and prepared by the best new methods; it is possible to confirm Dendy's previous description, and to add new facts. The figures 3–10 of Pl. V of this paper are drawn from sponges fixed by Champy-Kull's method, and then stained in Benda's alizarin and crystal violet.

In Pl. V, fig. 3, is drawn a choanocyte; its nucleus stained reddish brown, the nucleolus was violet, and the granules (G) in the cytoplasm also stained a deep violet. I believe that some of these granules, if not all, are to be regarded as the mitochondria of the cell. In certain cases the very large granules stained less densely than the smaller ones, and these may be yolk (with dense proteid content) or mitochondrial granules partly changed.

In Pl. V, fig. 4, is a collar cell just after it has begun to metamorphose into an oögonium. This cell lay in the collar epithelium, just beneath two normal choanocytes. The nucleolus (plasmosome) has enlarged, and the nuclear network stained less densely than that of most of the unchanged collar cells. Such cells as the one drawn in Pl. V, fig. 4, migrate from the flagellated cavity into the mesoglea, where they undergo further remarkable changes.

Figs. 5–10 are drawn from mesogleal oögonia; in fig. 5 the nucleolus has increased enormously in size, while the cytoplasmic granules derived directly from those already existing when the cell was still a choanocyte are still evident, but often shrunken in size. In subsequent stages the large plasmosome elongates and divides by transverse fission, a large piece being shot out into the cytoplasm, as in Pl. V, fig. 6, at N. In other cases large numbers of plasmosomes collect inside the oögonial nucleus; the latter seems to collapse bodily and the contained granules pass into the cytoplasm, as in Pl. V, figs. 7 and 8.

In a number of cases large pieces of the plasmosome are separated from the central nucleolus, and pass to the nuclear membrane; this becomes broken down, and the granules pass through, as shown in Pl. V, fig. 10.

In such stages a really extraordinary change comes over the hitherto spherical nucleus. Pl. V, fig. 8, shows an appearance which is quite usual; here the nucleus has more or less become

broken up, and in such cases it is difficult to identify the remains as being a nucleus. From a study of a number of oögonia at this stage it seems as if the nucleus becomes blown up with its contained nucleoli, suddenly bursts, and shoots its granular contents into the surrounding cytoplasm. One is impressed at all events by the collapsed and changed condition of the nucleus after it has parted with most of its plasmosome material.

In many cases it becomes possible to identify a thick halo of differentiated cytoplasm surrounding the nucleus, as shown in Pl. V, figs. 6 and 10, at H. One is irresistibly induced to believe that this halo is formed by materials squeezed, or at all events passively passing, out of the nucleus. In certain examples, as in Pl. V, fig. 6, the peri-nuclear halo contains vacuoles and granules, and is arranged in a radiating manner from the nuclear membrane.

Using Benda's alizarin and crystal violet stain, or even acid fuchsin and toluidin blue, it has been possible to show that the nucleolar or plastin material undergoes a change when extruded into the cytoplasm, or when it comes into contact with the cytoplasm. This is shown by such stages as in Pl. V, figs. 9 and 10; in each case the granules (G or N) after passing into the cytoplasm stain more densely in crystal violet than before. In fig. 10 the two plastin bodies at N stain more heavily than their parent body in the centre.

After the extrusion of the plastin materials the nucleus reforms as in Pl. V, fig. 9. Occasionally some of the extruded plasmosomes stain less heavily than their fellows, as at X. The nature of this peculiarity is not known.

That the extruded plasmosomes form the mitochondria of the ripe egg seems to me to be an attractive view. A number of authors (*2*, *7*) have identified these cytoplasmic granules as chromidia and have traced their origin to the nucleus. Subsequently the extruded plasmosomes break up (divide ?) into smaller pieces, and appear to grow and continue active within the cytoplasm.

Quite lately I have found that in the oögenesis of *Saccocirrus* the extrusion of nucleolar materials and the formation and presence of mitochondria in the cell are not related. As is well known, Hempelman and Buchner both describe in *Saccocirrus* the extrusion of nucleolar (plasmosome) fragments which later form "yolk." Now these nucleolar fragments in *Saccocirrus* simulate the staining, if not the fixing reactions of the mitochondria, and for a time I thought that the cases of the sponge and of this archiannelid might be similar. This seems to be far from being true; in *Saccocirrus* true mitochondria exist in the egg before the extrusion of the nucleolar fragments. In my last paper on sponge embryology (*3*) I came to the conclusion that true mitochondria did exist in *Grantia* collar cells, and that the so-called "chromidia" in the egg cytoplasm

described by Jörgensen and Dendy were mitochondria. In my previous work on the oögenesis of *Grantia* I found what I considered to be true yolk, and confirmed the previous descriptions by Jörgensen and Dendy of the presence of the "chromidia." I have pointed out that these bodies should not be called "chromidia," for they are not related to true chromatin. I still have doubts as to whether the yolk granules, the "chromidia," and the Golgi bodies are the only formed structures to be found in the sponge egg; and had it been possible I should have liked to have made many further trials with modified mitochondrial methods to try to detect a finer granulation which might be something apart from Jörgensen's "chromidia," which at present I believe to be the mitochondria. The only points which make me doubt an interpretation of these "chromidia" as mitochondria are:—

(*a*) Nucleolar "chromidia" (so-called) and true mitochondria both exist in *Saccocirrus*.

(*b*) The fixing reactions of the sponge "chromidia" are not exactly similar to those of most metazoon mitochondria.

Of course, neither of these points may signify, but I have thought it necessary to bring them forward. It should be remarked that the archiannelid oögenesis is probably unique in the animal kingdom, and the "chromidia" of the sponge in later stages of oögenesis approximate closely to the fixing reactions of the mitochondria of other animals.

Addendum I.

Dr. Bidder, of Cambridge, showed me recently a preparation of Sycon to illustrate what he calls "dolly" cells. One slide impressed me very much because it showed two large cells partly protruding from a "cloaca," and to each of these cells was attached a much smaller cell the expected size of, flagellate, and closely resembling a sponge spermatid. I consider that these cells found by Dr. Bidder might be changing spermatozoa which have become attached to the large cells, though it would not be possible to give an opinion of value until one had personally studied the material.

Addendum II.

A few months ago Mr. Julian Huxley showed me some of his slides illustrating his work on sponges (*6*). As is well known H. V. Wilson found that sponges could be strained through fine gauze so as to separate their individual elements, and many of the latter could come together again and regenerate to form a new sponge (*8*). Mr. Huxley repeated Wilson's work, and among the new sponges or regenerates procured by this method he found

some which seemed to be surrounded by bodies resembling spermatozoa; he kindly drew my attention to these examples, and allowed me to restain certain of his Sycon slides, from which I was able to come to a definite opinion that these bodies in question resembled the ordinary metazoon sperm in detail, and had a tail sheath staining in crystal violet. While it is possible to identify these as spermatozoa, the evidence that they are *sponge* sperms is much less complete; but two facts must be borne in mind: the sperm in *Spongilla,* according to Görich, is filiform and flagellate; the sperms in Mr. Huxley's slides were definitely attracted by the collar cell regenerate masses, and in some cases seem to have penetrated into individual collar cells. The main bulk of evidence is therefore that in the *Syconidæ* the sperm is flagellate and filiform, and this opinion is further supported by the figure 1 of Pl. V. in the present paper.

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X.—*A Universal Microtome.*

By Sir Horace Darwin, F.R.S., and Mr. W. G. Collins.

(*Read June* 16, 1920.)

Four Text-figures.

The Cambridge Rocking Microtome was designed and first made in 1885; it has been much used and undoubtedly is a successful instrument. The Universal Microtome has, we believe, all the good features of the Rocking Microtome, and at the same time has

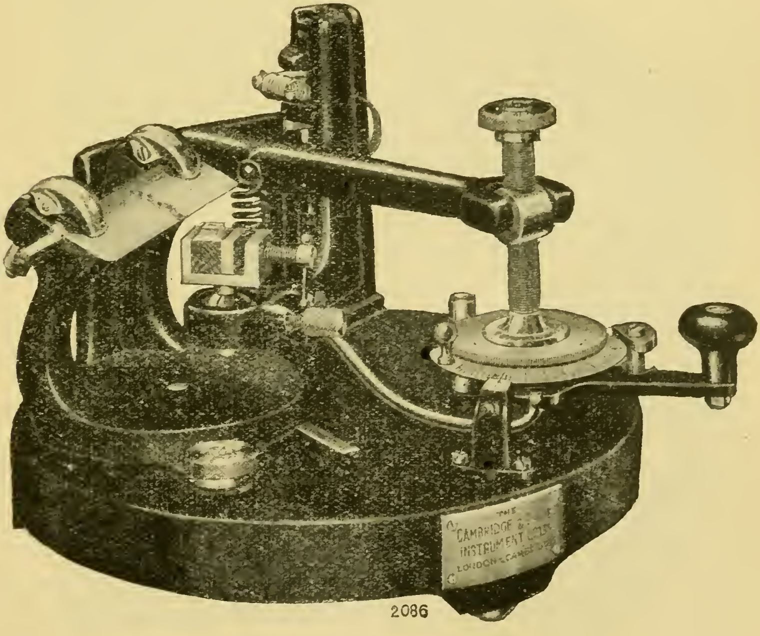

Fig. 1.

the additional advantage that flat sections are cut. The instrument is well adapted for cutting objects embedded in paraffin or celloidin, or frozen preparations; it is also convenient for the ribbon or serial method in paraffin, and for Apathy's "series on the knife" method in celloidin. This microtome differs in its

action and appearance from most other microtomes, and we will first give a short description of it, and then the reasons why we consider the special construction is advantageous, and further details of some of its parts.

Brief Description.

The microtome (see fig. 1), which is made almost wholly of cast iron, has a circular base 250 mm. in diameter, with three cork feet which rest on the table. The object moves and the knife is fixed. The knife is machine ground and is clamped at both ends to the knife-holder, but can be slid longitudinally in the holder to bring a different part of its edge into action, if one part is blunted. Its cutting edge is horizontal, and can be adjusted to give the best angle of cut. The knife-holder can be moved laterally and clamped to the base at any convenient position. It can be also rotated about a vertical axis so as to give a slicing cut—that is, the direction of the cutting edge of the knife can be placed at an acute angle to the direction of the movement of the object. The object is fixed in an orientating object-holder, very rigid in construction and carried at the outer end of a horizontal swinging arm. This swinging arm can rotate at its inner end about a vertical axis. Thus the object moves in a horizontal plane along the arc of a circle and not in a straight line. The action is like the swinging of a gate with the object carried at a point near the latch. In the microtome the hinges are constructed so as to allow both rotation and movement along the vertical axis of rotation of the hinges. It is by means of this vertical sliding movement that the object is raised between successive sections. The micrometer screw and nut for giving this vertical movement to the object are similar to that used in the Rocking Microtome. The method of feeding the screw forward and the handle for moving the object past the knife are also similar. In the new microtome the feed screw A (see fig. 2) is approximately vertical and is given a small rotary motion at the end of each stroke from a pawl B, carried on the oscillating handle C, which pawl engages with a large steel ratchet wheel D at the lower end of the screw. This partial rotation elevates the feed nut E on which is carried the outer end of the feed lever F. The design is such that this nut cannot rotate about the feed screw, but is free to rock with respect to the feed lever as it rises. The feed screw is supported in a conical seating at its lower end so that the nut and screw can adapt themselves to the movements of the feed lever. The large end of this lever which extends across the microtome is supported on horizontal knife edges, working on planes of the same design as the vertical knife edges and planes of the swinging arm. The axes of these two sets of knife edges are

therefore at right angles to each other, but do not intersect. At a point which we will call the "feed point" a projection on the feed lever intersects the vertical axis of the knife edges of the swinging arm and engages with this arm through a special connecting pin

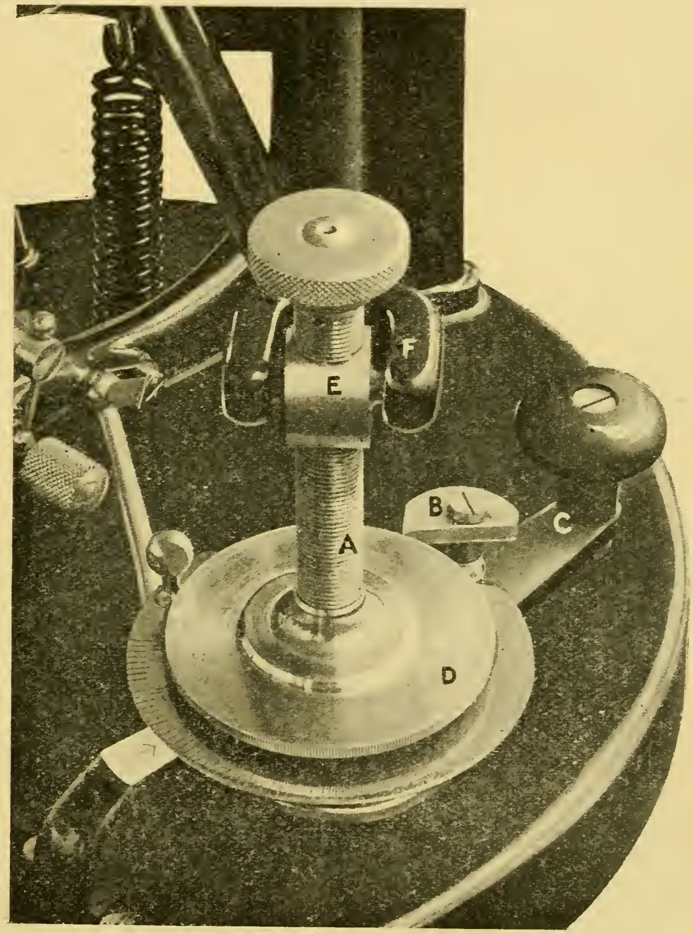

Fig. 2.

described below. It will be clear that if this feed point be between the feed nut and the fulcrum of the feed lever it will rise as the feed nut rises and carry the swinging arm with it. In this microtome the feed point is considerably nearer to this fulcrum than to the feed nut, and consequently the swinging arm has less vertical

motion than has the feed nut. At its lower end the connecting pin seats into a conical hole in the feed lever and at its upper end into a conical hole in the swinging arm. This pin is kept in compression and in geometric contact with both the feed lever and the swinging arm by means of a spring. It will be seen that this pin remains approximately vertical throughout the motion, and that the swinging arm is kept at a constant height during the cutting stroke, owing to its point of contact with the feed pin being on its axis.

Flat Sections.

In the Rocking Microtome the sections are cut from a cylindrical surface of 90 mm. radius. If the section is 5 mm. in diameter the maximum deviation of the surface of the cylinder from a plane is 0·035 mm. This is a small amount, and probably with soft tissues the deformation of the parts from the normal position caused by embedding or freezing is far greater than this. The advantage gained by cutting flat sections is sometimes more imaginary than real, but it is not infrequently some advantage, and with large sections it is well worth having.

Horizontal Sections.

The plane of the sections is horizontal; this is advantageous for paraffin embedded sections as the correct orientation of the object is far easier, and this position is essential for celloidin embedded sections as the lubricating liquid remains on the knife, and it is possible to float off the sections, which is not the case where the side of the knife is in a vertical plane. For frozen sections a horizontal position is essential. A dissecting lens and stand can be conveniently used during the precise orientation of the object. Ribbons of paraffin embedded sections can be made with ease by this microtome, although perhaps their manipulation requires slightly more care than with the Rocking Microtome. The clamps for the knife have been designed to project only a little above the knife itself, and so do not interfere with the convenient use of the section lifter; thus delicate handling of the sections is simpler, and the danger of damaging them is lessened.

Uniform Sections.

In all cases successive sections should be as nearly as possible of equal thickness, and each section should be of the same thickness throughout. With a good well-sharpened knife a section in paraffin can be cut as thin as 1 micron. If the sections with a

thickness of 2 microns vary by not more than ± 10 per cent. of their thickness, the relative displacement of the knife and object from any cause must be less than $\frac{1}{5}$ micron (0·0002 mm.). This is a very small amount, and it is clear that the instrument must be rigid, and that there must be no shake in any of the parts. Each moving part must in fact move with great precision along its correct path. The sections are cut by moving some part of the instrument by hand, and even with the most careful use there is some uncertain pressure of the hand at right angles to the direction of the movement of the handle, and there must be some bending of the frame. The frame should therefore be rigid. But it is more important still to design the instrument so that this uncertain force has little or no effect in bending those parts which will alter the thickness of the sections. There is also a component of the cutting force at right angles to the plane of the section acting between the cutting edge of the knife and the object. This force is not constant, especially with hard sections. These considerations show the importance of rigidity in the knife, the object holder, the moving parts, and the frame. All these parts bend when force is applied to them, and it is of comparatively little use to make the frame stiff if the knife or the object holder is capable of springing under the forces acting on them.

In some sliding microtomes the knife is clamped at one end only; this is particularly objectionable when cutting objects embedded in celloidin with nearly the full length of the knife in use, as the sections are cut by a part of the knife at a considerable distance from the clamped end, and the knife bends more easily. Clamping the knife at both ends very greatly increases its stiffness. In the new microtome the knife is clamped rigidly at both ends in the adjustable knife holder, which can be firmly clamped to the base of the instrument.

Orientating object holders are often not sufficiently rigid, and have a large number of joints with possibility of slackness, and when provided with means for tightening such joints have the disadvantage that they must be loosened and tightened after each adjustment. The orientating object holder we have designed for this microtome is new and is very rigid.

There are other causes of want of uniformity in the sections. In microtomes with large sliding surfaces the irregular distribution and the varying thickness of the film of oil between the surfaces may influence the thickness of the sections. The collection of dust on the oiled surfaces will have the same effect. The oxidation of the oil will also cause trouble.

In the new instrument no oil is essential on any surface concerned with the precise guiding of the object, although it is desirable with the view of preventing rust that such surfaces be oiled or greased. The moving surfaces in contact are of small area

and the pressure between them is large; this prevents dust from getting in and ensures an extremely thin film of oil, which will not vary in thickness by an appreciable amount. These bearings are a slightly modified form of the knife edge and plane used with such success in the Rocking Microtome.

Another cause of irregularity in the thickness of the sections is the looseness produced by the wear of the various slides. Usually the slides require the attention of a skilled mechanic for their proper adjustment. In some instruments the object is carried on a reciprocating slide with a comparatively long travel; this slide will wear, and then precise cutting becomes impossible until skilled attention has been given to the instrument.

In the new microtome the geometric principle is adopted in the chief moving parts, ensuring accurate working without shake, even after much wear of the rubbing surfaces. The wear at these surfaces is, however, small, but even if it were large it would be all taken up automatically by springs, and thus no shake is possible. Skilled attention is not required to keep the microtome in good order.

Manipulation.

In cutting sections with a microtome it is advantageous that the force acting on the object during cutting should be transmitted accurately to the hand. This is markedly the case in this microtome. The connexion between the hand and the object is rigid, whereas in the Rocking Microtome the cutting force is due to a spring. But what is more important, the friction and inertia of the moving parts is small. In the majority of sliding microtomes the friction is considerable, and in microtomes of the Minot pattern there is a considerable amount of inertia of the moving parts, and the friction is not small and is somewhat uncertain in amount. The connexion between the hand and the object is by means of a crank and connecting rod, and thus the ratio of the force on the hand to the force on the object varies greatly during the rotation of the handle. The ratio of the velocity of the hand to the velocity of the object also varies during the rotation of the handle. A variation of the ratios of the forces and velocities takes place in the Universal Microtome, but the variation is much less. A fly-wheel of considerable weight is usually fixed to the crank axle in the Minot type of microtome. This increases the inertia of the moving parts and ensures more uniform velocity of the hand and less uniform velocity of the object relatively to the knife. We find that if the cutting speed is too high, the edge of a hollow ground knife vibrates and irregular work may be produced. If the cutting speed is uniform throughout the stroke it is easier to prevent it ever becoming too great, and if the inertia of the

moving parts is small the speed of cutting can be regulated instantly, or the object can be stopped even while a section is being cut.

These considerations lead us to think that a continuous rotation of a handle is not the best method of giving the reciprocating movement of the object in a microtome, and we have adopted a similar design to that used in the Rocking Microtome. Many years' experience have shown that this movement of the hand is convenient and the mechanism is simple and efficient. A radial bar which can turn about a vertical axis at one end is made to oscillate backwards and forwards through a large angle by means of a handle fixed at its other end. This oscillation moves the object past the knife and feeds it upward at the end of the return stroke, the feed occurring after the object has completed its travel.

The foregoing considerations would lead one to expect that with very little skill good sections can be cut with this microtome, and we find that this is the case. We also believe that with objects which are difficult to cut, the fact that the force exerted by the knife on the object is directly transmitted to the hand will enable an operator to make the best use of his skill, and may therefore enable him to get better results than would otherwise be possible.

The amount of feed for giving any required thickness of section is set instantly and requires no clamping. Each division on the scale corresponds to 1 micron in thickness, and sections as thick as 35 microns can be cut.

The feed or micrometer screw is fitted with a milled head which permits of very ready fine adjustment of the object to the knife. The manipulation of the orientating object holder is simple. The object (see fig. 3) is clamped in a vice B, which has a cylindrical stem C sliding in a cylindrical hole in the sphere D. The sphere is cut almost completely through along the axis of the hole, and the screw E which clamps it also serves to clamp the stem of the object holder, owing to the geometrical mounting, at whatever angle the sphere may be in its seating. To orientate the object the clamping screw is slackened, and the object can then be rotated in any direction through an angle of 15° from the vertical, owing to the movement permitted to the sphere. It can also be rotated through any angle about a vertical axis, and can be raised or lowered owing to the movement of the stem in the sphere, and then rigidly clamped by the single screw.

The knife holder is easily adjusted to give a slicing cut; it can also be moved so that sections can be cut with new parts of the knife as it becomes blunt or damaged. The knife thus requires less frequent sharpening, much time is saved, and good work can

be done at once after the knife has been shifted. The knife F (fig. 3) itself is longer than the distance between the two clamps H, H_1, and can be shifted lengthwise in the clamps, again increasing the proportion of the cutting edge of the knife that can be used. The knife holder can be moved so as to place the object as near the knife as desired before the cutting begins. The knife can also be adjusted in the knife holder. To do this the knife is

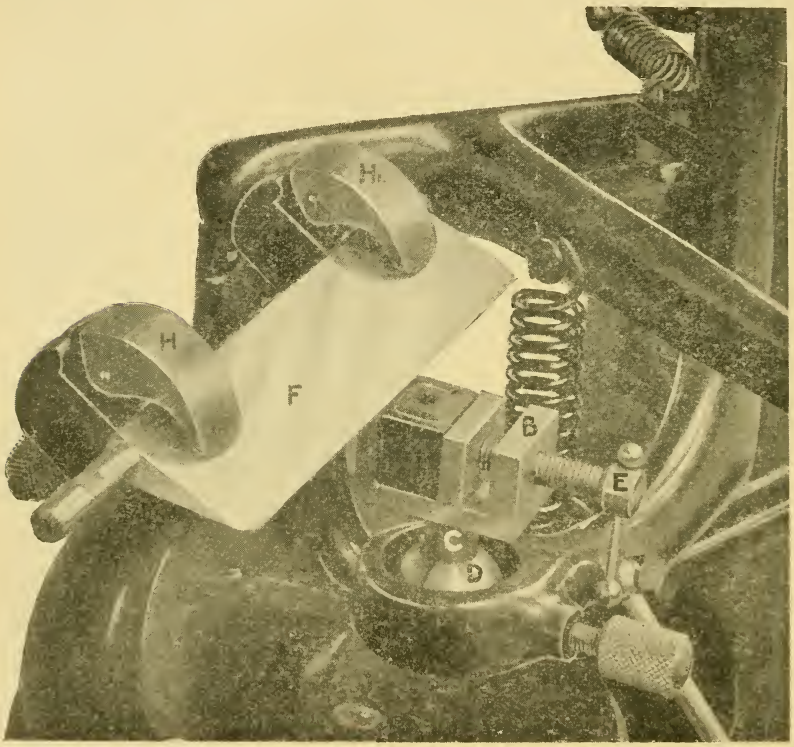

Fig. 3.

rotated about a line parallel to the cutting edge and then clamped in that position. The movement is given by a double wedge (fig. 4), which lifts the back of the blade at the two places where it is clamped. The wedge is moved by a screw with a divided head F, indicating the amount of the angular movement. The best clearance angle for cutting depends on the material to be cut and on the form of the cutting edge of the knife; when this angle

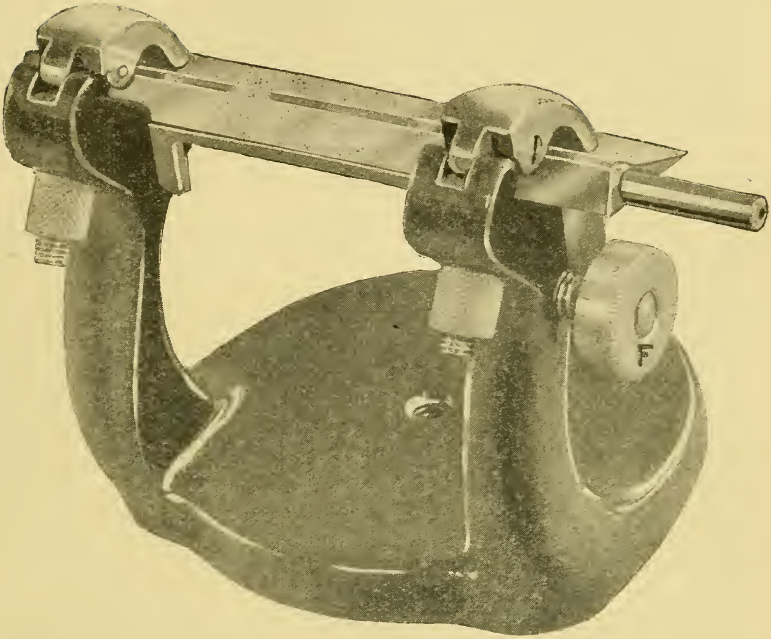

FIG. 4.

is found by trial the knife can be re-set at the same angle if the graduations on the divided head have been noted.

OTHER DETAILS OF THE DESIGN.

A well-designed instrument should work well when worn or damaged, and it should be robust and have few or no delicate parts requiring careful handling. We believe that the new instrument fulfils these conditions. It is as robust as the Rocking Microtome, and will stand rough treatment equally well; it will cut good sections after long use, or even when slightly damaged. The principle of geometrical design has been largely used in the moving parts, so that no unnecessary constraint is given to them and shake is automatically eliminated. The nut on the micrometer screw is an exception; it is always pressed in one direction and there can be no shake. The clamping devices for the knife holder and the knife itself are not geometric, but there is no movement when these parts are clamped, and we believe that it is best not to make them geometric.

The other places where movement takes place and where the

fit is geometric are :—The bottom bearing of the micrometer screw; the connexion of the micrometer screw nut to the end of the feed lever; the fulcrum of this lever; the fulcrum of the swinging arm; the connexion between this lever and the swinging arm carrying the object; and the clamp for the sphere carrying the object holder.

Vertical Movement of the Object.

As previously mentioned a difference of 10 per cent. in the thickness of two successive sections amounts to 0·0002 mm. with sections 0·002 mm. thick. It is clear that the nut on the micrometer screw must transmit its movement to the object with great accuracy. Now there must be friction in the vertical movement of the swinging arm on its knife edges. The first very small movement of the micrometer screw will move the nut a very small amount; the first effect will be to bend the lever connecting the nut to the sliding part, and this bending will go on till there is sufficient force to overcome the friction of the slide. It would seem that the relation between the movement of the object and the micrometer screw might not be perfect. The danger of this error is increased because the nut is connected to the slide by a lever, and this must have more spring in it than when the connexion is more direct. We considered this point and came to the conclusion that it would not cause an appreciable error for the following reason, and experiments proved we were right:—

The vertical sliding part is also the axis of rotation of the swinging arm. Now it is well known that a rotating shaft even when carrying a heavy wheel can be moved endways by the slightest force; although when it is at rest the force required to move it is great. We all know that less force is required to pull a cork out of a bottle if the cork is rotated at the same time, and most of us have done this without realizing the reason. The same thing happens in the vertical axis of the microtome; the micrometer screw is turned and the swinging arm rotates; this causes a slight movement of the rubbing surfaces in the vertical slide in a direction at right angles to the direction in which the sliding parts should move. This eliminates the effect of friction so far as it acts in the vertical direction in which the sliding motion takes place, and the ratio of the movement of the micrometer screw to the vertical movement of the object is constant.

A defect in many microtomes is that either the diameter of the micrometer feed screw is too small or that the pitch is very fine, and not infrequently both of these defects are present in the same instrument. In the first case the screw is readily bent, and in the second case the amount of wearing surface between the nut and the screw on which it works is small, and the wear soon

becomes serious. In this microtome the screw is robust and of large diameter, and the pitch is 1 mm., which is not too fine.

The knives are ground in a machine which gives a true rectilinear movement to the grinding wheel, thus ensuring a straight cutting edge. This is especially important when a slicing cut is used for cutting sections. The back of the knife is also straight and parallel to the cutting edge. The knife is in fact a true prism. When this condition is fulfilled the cutting edge remains straight when the knife is sharpened on the hone, and it is far easier to produce a thoroughly satisfactory cutting edge. By the special process of grinding adopted it is easy to make the knives more or less hollow ground to suit different conditions.

The microtome was designed and made by the Cambridge and Paul Instrument Company.* In the design of the mechanism it resembles the Rocking Microtome, which was designed and made in the Cambridge Works. Many of the good features in this instrument are due to the care and thought given to them by members of the staff of the company. The method of adjusting the cutting angle of the knife is the design of Mr. C. C. Mason, and the orientating object holder is due to Mr. J. L. Orchard.

Summary.

We believe that the advantages of this microtome may be briefly summarized as follows :—

1. The sections are flat and are cut in a horizontal plane.
2. Sections of any thickness in steps of 1 micron may be cut between 2 and 35 microns.
3. Owing to the rigid and geometric design of the instrument, each section is of uniform thickness, and successive sections are of equal thickness.
4. Most of the cutting edge of the knife can be used so that the knife requires the minimum amount of sharpening.
5. The object holder can be readily adjusted in every direction.
6. The instrument is robust.
7. As there is little friction and the moving parts of the instrument are light, it is possible to "follow through" with one's hand whilst the sections are being cut.

* Patents have been applied for on this instrument.

XI.—*Preliminary Tests on the Homologue of the Golgi Apparatus in Plants.*

By A. H. Drew, D.Sc., F.R.M.S.

(*Read April* 21, 1920.)

Four Text-figures.

At the March Meeting of the Royal Microscopical Society I demonstrated certain cytoplasmic inclusions in the cells from the root-tip of the onion closely resembling or identical with the Golgi apparatus of animal cells. Guilliermond (*1*)* has recently described similar appearances in the roots of the pea and barley as filamentous mitochondria, and noted their resemblance to the Golgi apparatus. The present note puts on record the appearances seen in the onion and the method used.

Growing root-tips are fixed for twenty-four hours in formol, 20 c.cm.; cobalt nitrate, 2 grm.; sodium chloride, 0·8 grm.; water to 100 c.cm. (preferably at 37° C.). Frozen sections are cut after soaking in gum-syrup for at least an hour. The sections, after washing in water, are fixed on gelatin-coated slides with formalin, rinsed in water to remove excess of formalin and mordanted at 50°–55° C. in chromic acid, 4 p.c., osmic acid, 2 p.c., equal parts, on the slide for varying periods—fifteen minutes to one hour or longer. The staining is then carried out as follows:—

Rinse in water and stain with iron-alum, 3 p.c., fifteen minutes, followed by ½ p.c. hæmatoxylin fifteen minutes at 50° C. Differentiate in 3 p.c. iron-alum, cold, till the nuclei are pale brown, transfer to 2 p.c. pyridin two minutes, wash in running water two to five minutes and mount in xylol-balsam.

In specimens chromated for the shorter periods, the mitochondria only are visible in addition to the nuclei. These are usually of the granular variety, but also occur as very fine short rods staining very black with hæmatoxylin. They are extremely numerous and are scattered over the whole of the cytoplasm (see fig. 1). The mitochondria may also be well seen when stained by Hollande's chloro-carmine (*2*), but the Golgi apparatus is not stained by this method. In sections mordanted with the chromosmic solution for longer periods, it is found that the mitochondria stain very much more faintly, and new structures begin to make

* The italic figures within brackets refer to the Bibliography at end of the paper.

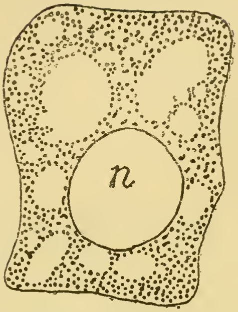

Fig. 1.—Central cell of onion root. Mitochondria only stained, no Golgi apparatus. Short mordanting with chrom-osmic mixture on slide. Iron-alum hæmatoxylin. × 1300/1.

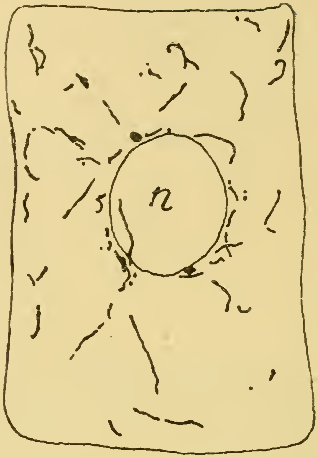

Fig. 2.—Central cell of onion root. Long mordanting with chrom-osmic mixture. No mitochondria: Golgi apparatus long and short filaments forming a dense network around nucleus and scattered filaments throughout cytoplasm. × 1800/1.

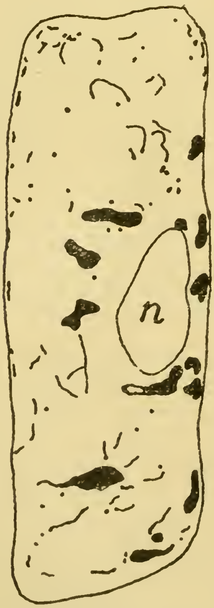

Fig. 3.—Cell midway between centre and surface of onion root. Long mordanting with chrom-osmic mixture. A few mitochondria and delicate and coarse Golgi elements. × 1800/1.

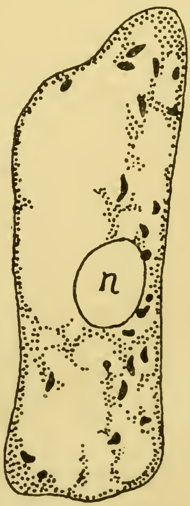

Fig. 4.—Surface cell of onion root. Long mordanting with chrom-osmic mixture. Granular mitochondria and oval lenticular Golgi elements. × 1300/1.

their appearance. These consist of darkly staining oval and elongated bodies, many clustered around the nuclei. They are most easily demonstrated in the superficial cells (see figs. 3 and 4), and in them they are almost entirely short, oval, flattened elements. If the mordanting be pushed still further, the mitochondrial elements no longer stain, whilst the Golgi apparatus stains more intensely and becomes evident in the great majority of the cells. In the central cells, especially, it occurs as coarse and irregular filaments and rods, many closely adherent to the nuclei (see fig. 2). (The same effect of prolonged mordanting has been demonstrated in animal cells, where again it is found that the shorter chromating only brings out the mitochondria, whilst these stain more faintly after longer mordanting and the Golgi apparatus appears).* From their general appearance, their relation to the nucleus, and their behaviour with chrom-osmic acid it is reasonable to class these structures in plants with the Golgi apparatus of animal cells. This is also suggested by their sensitiveness to external conditions, as well as to the histological differentiation of the cells at the time of fixation. During mitosis the Golgi apparatus is distributed between the two daughter-cells, but I have not been able to ascertain with what degree of accuracy it is divided between the two.

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* The Cajal silver method is not successful with plant tissues, but sections stained in this manner showed that the elongated bodies stained with the silver, which is additional evidence as to their identity with the Golgi apparatus.

SUMMARY OF CURRENT RESEARCHES

RELATING TO

ZOOLOGY AND BOTANY

(PRINCIPALLY INVERTEBRATA AND CRYPTOGAMIA),

MICROSCOPY, ETC.*

ZOOLOGY.

VERTEBRATA.

a. Embryology, Evolution, Heredity, Reproduction, and Allied Subjects.

Interstitial Cells in Ovary of Bats.—M. ATHIAS (*Arch. Biol.*, 1919, **30**, 89–212, 1 pl.). Interstitial glandular tissue was found in all the bats studied; in Vespertilionidæ it forms the greater part of the ovarian stroma; in Rhinolophidæ it is much less developed; it occurs in the ovaries of the fœtus and the young animal, as well as in adults. During pregnancy and lactation the interstitial tissue is at its maximum; in autumn it suffers considerable reduction; towards the middle of winter it begins to increase again. The tissue consists of masses of cells separated by a connective reticulum, rich in blood vessels. In this respect the architecture is like that of an endocrine gland. In Vespertilionidæ the interstitial cells occupy the whole extent of the cortical or parenchymatous zone of the ovary, but always leave a clear band at the periphery below the germinative epithelium. This more or less narrow band includes the young oocytes and the primordial follicles. The medullary zone, the importance of which varies a good deal in different species, contains the same elements, isolated or in small groups. In the Rhinolophidæ the interstitial elements are situated round about the atresic follicles, and there are also sometimes masses in the inter-follicular spaces and in the vascular zone of the ovary. The interstitial cells have glandular characters—abundant chondriome, enclosures of lipoid substance, siderophilous protoplasm, and nuclei marked by very distinct polychromaticity. The chondriome consists of chondrioconts and mitochondria. The lipoid enclosures are certainly the results of secretory processes. In young females the interstitial

* The Society does not hold itself responsible for the views of the authors of the papers abstracted. The object of this part of the Journal is to present a summary of the papers *as actually published*, and to describe and illustrate Instruments, Apparatus, etc., which are either new or have not been previously described in this country.

cells arise from all the connective elements of the stroma of the ovary. Later on they arise chiefly from the cells of the internal theca of the atresic follicles. They form first the false corpora lutea as a transition stage. In the adult there is also a transformation of cells of the inter-

A group of interstitial cells in the ovary of an adult *Serotinus*, showing alveolar cytoplasm and numerous mitochondria.

follicular stroma into interstitial cells. The interstitial cells in the bat do not seem to have to do with rut and ovulation, but probably with the nutrition of the genital system and with the determination of the secondary sex characters. J. A. T.

Parthenogenetic Development and what it Suggests.—M. Herlant (*Arch. Zool. Expér.*, 1919, **58**, 291–314). (1) The simple activation of the ovum of *Paracentrotus lividus* by means of butyric acid is characterized by the formation of a monaster which repeats itself rhythmically without ever provoking segmentation. Only after numerous attempts at division does the ovum begin to suffer self-destruction by cytolysis. But this is merely the final result of cytological conditions incompatible with life; it is not their cause. (2) Following Loeb's method, Herlant subjected the ova, activated by butyric acid, to hypertonic solution. A new reaction is artificially induced which gives the monaster the bipolarity which it lacks. This makes segmentation and development possible. (3) No structure in the cell is indispensable to division of the cell as a whole or of parts of the cell. The division of the cell is the sum of a series of particulate and independent divisions. Thus the division of the chromosomes is not the consequence of the division of the centrosome. There is a general physico-chemical change in the economy of the cell. J. A. T.

Spermatogenesis of Horse.—K. Masui (*Journ. Coll. Agric. Imp. Univ. Tokyo*, 1919, **3**, 357–76, 3 pls.). The resting nucleus of the spermatogonium contains a large nucleolus and several small chromatin masses. In the metaphase of the spormatogonia the numerous chromosomes are divided at the same time. Many symmetrical pairs were

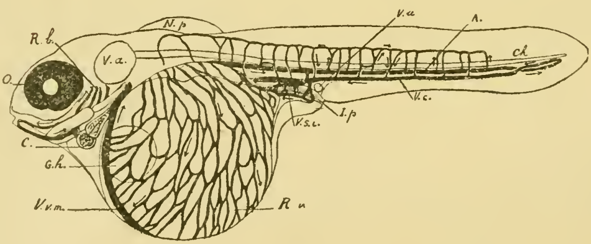
distinguishable, but a count was not possible. The resting nucleus of the primary spermatocyte contains a large chromatin nucleolus. The conjugation of the chromatin threads takes place by parasynapsis. The chromosome nucleolus presents itself throughout the synapsis and the growth stages. In the primary spermatocyte the idiozome is conspicuously present. The number of chromosomes in the first division is nineteen—namely, eighteen bivalent and one accessory. The first division is reducing and heterotypic. The accessory chromosome now passes undivided to one pole, thus producing two groups of spermatocytes, one with and the other without the accessory chromosome. The resting stage of the secondary spermatocytes seems to be very short. The second pairing of the chromosomes in the second division was not observed. The second division is equal and homotypic. The accessory chromosome divides like the ordinary ones. The behaviour of the centrosome in the development of the spermatozoa is almost the same as that described by Meves for man. The chromatoid corpuscle, appearing in the growth stage, seems to be cast out finally. The mitochondria appear during the postsynaptic stage. In the spermatids most of them give rise to a mass similar to the "Nebenkern" of insects; the main portion finally comes to occupy the middle part of the spermatozoon. J. A. T.

Spermatogenesis in Ox.—K. Masui (*Journ. Coll. Agric. Imp. Univ. Tokyo*, 1919, **3**, 377–403, 3 pls., 1 fig.). In embryos and quite young animals the spermatogonia divide by amitosis. The cells seem to be degenerating, being used as nutritive materials by others. The resting nuclei in both the last and the penultimate spermatogonial generations usually contain a large nucleolus and a small chromatin mass. The number of chromosomes in the spermatogonia is thirty-three; they vary considerably in size and form, but occur in pairs. Each splits longitudinally along the cleft which appeared in the spireme stage. No special chromosome with different behaviour was to be seen. In the telophase of the last spermatogonia the chromosomes are not fused. They become lengthened into leptotene threads. Conjugation of chromosomes probably takes place by telosynapsis during the synaptene stage. In this stage the leptotene threads converge towards one side of the nucleus, leaving a clear space on the other side. During the final prophase the longitudinal splitting and transverse constriction of the chromosomes are to be seen. The chromosomes are divided along the constriction in the first reducing division. In the second reducing division all the chromosomes become so placed that the line of the longitudinal split coincides with the equatorial plane, and along this line all the chromosomes (the accessory ones included) are divided at the same time. Thus it is simply an equation division. In the spermatogonia and the spermatocytes the centrosome is so minute that it cannot be distinguished from the other granules. Its changes during the formation of spermatozoon can be followed and are seen to differ considerably from those in the horse. The chromosome nucleolus or the accessory chromosome can be traced throughout the growth stage and the reduction division. The idiosome appears as a cytoplasmic

body in the growth stage, and during the formation of the spermatozoon it becomes more and more conspicuous, till it assumes the appearance of a small spherical body and comes to be situated in a depression at the anterior part of the nucleus. It seems to have no connexion with the centrosome. Mitochondrial granules are abundant during the growth stage. Second pairing of chromosomes is not found, but as in the case of the horse incomplete fusion of the chromosomes is seen to occur. In such a case nine or ten chromosomes are occasionally to be counted. The chromatoid corpuscle cannot be found, but during the reduction division a small spherical body, staining faintly with iron-hæmatoxylin, appears in rare cases in the cytoplasm. J. A. T.

Development of Gobies.—C. G. Joh. Petersen (*Report Danish Biol. Stat.*, 1920, **26**, 45–66, 3 pls.). Notes on the young stages of five species of *Gobius* and of *Lebetus*, *Crystallogobius*, and *Aphya*, with particular attention to the pigmentation at various stages. The eggs of gobies are found in enormous numbers in Danish fjords; the development as a rule takes place in less than a year; there is considerable migration of the adults of several species. The chief aim of the paper is to facilitate the identification of the young stages of different species of Gobiidæ. J. A. T.

Development of Vascular System in Embryo Stickleback.—R. Anthony (*Arch. Zool. Expér.*, 1918, **57**, 1–45, 1 pl., 31 figs.). A study of



Larva of Stickleback (*Gasterosteus gymnurus*), thirty-eight hours after hatching.

O., eye; *C.*, heart; *V.a.*, auditory vesicle; *R.b.*, branchial rays; *G.h.*, oil globule; *V.v.m.*, median vitelline vein; *R.v.*, vitelline plexus; *N.p.*, pectoral fin; *V.s.i.*, sub-intestinal vein; *I.p.*, posterior intestine; *V.u.*, urinary bladder; *V.c.*, caudal vein; *A.*, aorta; *Ch.*, notochord. The arrows indicate the direction of the blood-current. The pigmentation is not indicated.

the beginnings of the circulation and of the vitelline circulation in particular in *Gasterosteus gymnurus*, with comparison with other Teleosteans. The primitive pathway of the blood returning to the heart from the aorta is a simple large venous vessel, fed by caudal, anal, and sub-intestinal veins, which runs to the left on the vitellus. There is a complete circuit before there is a vascular vitelline network. The first vitelline circulation in the stickleback is entirely venous. But when the vitelline

network is established, the vitelline circulation becomes partially arterial, in virtue of the development of the mesenteric artery and its vitelline branches. There is a marked asymmetry in the vitelline circulation; bilateral symmetry is not established until the absorption of the yolk is completed. The primary circulation in the stickleback is very like the primitive circulation of Amphioxus, though the stickleback is far from being archaic. J. A. T.

Development of Shoulder-Girdle of Pig.—F. B. HANSON (*Anat. Record*, 1920, **18**, 1–21, 28 figs.). There is a permanent supra-scapula, in which no centres of ossification appear. In the entire shoulder-girdle there are only two ossific centres: one for the scapular blade and one for the subcoracoid. Coracoid process, acromion, and clavicle are aborted. The pig's scapula is at once primitive and degenerate.

J. A. T.

Eye-colour in Birds.—C. J. BOND (*Journ. Genetics*, 1919, **9**, 69–81). An analysis of certain factors concerned in the production of eye-colour in birds. The "bull" eye owes its black or dark colour to the absence of pigment on the anterior surface of the iris. The delicacy and translucency of the iris tissues allow the posterior uveal pigment to shine through, and this gives an appearance of blackness. Another type is the "pearl" eye, where anterior iris pigment is absent, but the iris tissues are not translucent as in the "bull" eye. They are crowded with granules which are themselves colourless, but prevent the passage of transmitted light, and when seen by reflected light give a grey-white appearance to the surface of the iris. Another type is the "yellow" or "gravel" eye, due in the pigeon to a network of branching cells crowded with small spherical yellow granules. These cells lie on the anterior surface of the iris; they cover the capillary blood vessels and surround the striated muscle fibres of the iris, which in the pigeon are themselves free from pigment. Amongst birds, as amongst mammals, quite a large number of species possess anterior iris pigment which passes through all grades of brown up to black. With some exceptions, notably the Silky Fowl, the black iris is associated with black feather colour, and in its deeper grades with black-leg colour. Histologically the brown (in the darker shades) and the black iris are produced by a well-defined layer of characteristic branching cells, which contain dark brown or black pigment, on the anterior surface of the iris. These cells intercommunicate by their branches and form a plexus of pigmented cells thickest over the capillaries in the peripheral or middle zones of the iris. The author deals also with the "black" eye in fowls, with the "triplex" eye, containing two kinds of anterior iris pigment, the "ruby" eye (due to a surface layer of branching cells with yellow pigment, which surround the capillaries on the anterior surface of the iris), and the "parti- or zone-" coloured iris. He contributes notes on the genetics of the various factors. Some special cases of coloration are analyzed. Thus in Lawes' Bird of Paradise a brilliant colour effect is produced by the combination of three factors: (1) thinness and translucency of the iris tissue, allowing the uveal pigment to shine through;

(2) the absence of anterior yellow pigment cells in the inner zone ;. and (3) a peculiar physical conformation of the connective tissue cells in this area. A parallel fibrillation of cells acts as a diffusion grating and causes light to be reflected from the anterior surface of the iris at a certain angle as blue in colour. J. A. T.

Transplanting Cerebral Hemispheres of Amblystoma Larvæ.—H. Saxton Burr (*Journ. Exper. Zool.*, 1920, **30**, 159–69, 9 figs.). The cerebral hemisphere and nasal placode were transplanted to other places, especially the region just posterior to the right limb. In every case the transplants showed a healthy development. The successful results of the transplantation of the cerebral hemispheres show that the factor which stimulates the growth phase of nervous development is not the functional activity of the end organ, but the ingrowth of peripheral neurones. In the transplanted hemisphere, the central grey matter is restricted, particularly in the regions of the nucleus medianus septi and in the primordium hippocampi. The absence of ascending fibres reduces the size of the lateral forebrain tract and practically prevents the formation of the columna fornicis and the fimbria complex. A vascular pia mater is formed about the transplanted hemisphere, and a choroid plexus may be formed from properly placed blood vessels. J. A. T.

Regulation in Anuran Embryos with Spina Bifida Defect.—H. V. Wilson and Blackwell Markham (*Journ. Exper. Zool.*, 1920, **30**, 171–88, 5 figs.). In fishes and amphibians it frequently happens that something interferes with the normal movement of the blastopore lip over the yolk. In these cases the anterior end of the axial body develops in front of the blastopore lip and is continuous behind with the two halves of the latter. The authors studied embryos of *Bufo* and *Chorophilus* in which blastopore closure was inhibited, and they observed an interesting regulatory process. Instead of the two lateral blastopore lips fusing in the midline, the blastopore is shifted over toward one side, and from a single lip a backward extension of the axial organs is produced. Such a tadpole was reared to a stage in which external gills had been absorbed, and internal gills and opercular cavity formed. J. A. T.

Effect of Starving Young Rats.—C. M. Jackson and C. A. Stewart (*Journ. Exper. Zool.*, 1920, **30**, 97–127, 5 charts). Albino rats fully re-fed after underfeeding from birth to three, six or ten weeks, or from three weeks to nearly a year of age, grow variably, but usually fail to reach the normal adult size. The ultimate effect varies according to the length of the underfeeding period, the age at which inanition occurred, the sex (body weight more affected in males), the severity and the character of the inanition. The effects on particular systems and individual organs are noted. Thus the ovaries are markedly under weight, which probably accounts for the reduction of reproductive capacity marked after long underfeeding. But the abnormalities of weight are usually slight, and in general it may be said that the organs

and parts are almost normally proportioned in the permanently stunted rats. Thus the early starvation apparently retards or inhibits the later growth process of the body as a whole, with a few exceptions. J. A. T.

Results of Early Removal of Thymus Glands in Tadpoles.—BENNET M. ALLEN (*Journ. Exper. Zool.*, 1920, **30**, 189–200, 1 fig.). Experiments with *Rana pipiens* showed that the thymus glands from their very inception exert no influence upon growth or upon the progress of metamorphosis. They are not at any stage indispensable to life, nor does their removal cause any marked deficiency in the general metabolism of the body. Their extirpation does not affect the gonads, nor the thyroid glands, nor any internal feature. J. A. T.

Parathyroid Glands of Thyroidless Toad Larvæ.—BENNET ALLEN (*Journ. Exper. Zool.*, 1920, **30**, 201–10). Removal of the thyroid glands of *Bufo* causes a very marked hypertrophy of the parathyroid glands, so that they grow to many times the normal volume. There is not in these parathyroids any deposition of colloid or evidence of the assumption of a vicarious relationship. There are no noticeable histological peculiarities in these hypertrophied parathyroids. J. A. T.

Breeding of Dog-Perch.—JACOB REIGHARD (*Report Michigan Acad. Sci.*, 1913, **15**, 104–5). In this fish the female is pursued by several males, and after a tortuous course settles to the bottom. A male takes position over her with his pelvic fins clasping her head and his tail at the side of hers. Rapid vibration of the tail and fins (pectoral and pelvic) of both sexes excavates a little pit in the sand. The eggs are emitted, fertilized and buried. Each egg is weighted by a coating of adhering sand-grains. Supernumerary males crowding round attempt to supplant the pairing male. After spawning is finished at a pit the female at least leaves the eggs. She repeats the process at many pits. The supernumerary males (and perhaps the pairing male) devour such eggs as they can get. There is no parental care. There is colour dimorphism between the sexes, but this is not the basis of discrimination. If a male, substituted experimentally for a female, moves rapidly and then stops on the bottom, it is treated by other males as a female.
J. A. T.

Factors in Variation.—HEBER A. LONGMAN (*Proc. R. Soc. Queensland*, 1920, **32**, 1–18). Against the view that evolution is an unpacking of an original complex the author emphasizes the real newness of the pouch of marsupials, the patagium of parachuting mammals, the venom fangs of snakes, the pharyngeal teeth of fishes, and the copulatory apparatus of the male dragon-fly. He suggests that the evolution of environments would provide stimuli which might have cumulative effects in many generations. He lays emphasis on the importance of environmental change in inducing mutations. The general aim of the paper is to suggest a reconsideration of Lamarckism.
J. A. T.

The Method of Evolution.—E. W. MACBRIDE (*Scientia*, 1920, **14**, 23–33.) By the "force of heredity" is meant the tendency of the

offspring to resemble the parent. It is obvious that in some way this force must be modified as time progresses, otherwise evolution could not take place, and the manner and means of this modification is just what we mean by the phrase "method of evolution." Darwin and Wallace assumed that small variations are heritable, and further that the force which produced a deviation of heredity would continue to act in the same direction in succeeding generations. "Pure line" investigations are against the theory that progressive results can be attained by selection of these small quantitative variations. Thus emphasis has been laid on the importance of sports or mutants. But mutations tend to be of the nature of "cripples"—deviations from the normal which are notoriously unlike the differentiating characters which distinguish allied species from one another. If we have to reject small individual differences and larger occasional mutations as the raw material of evolution, there remains only a third alternative—that evolutionary change is due to the inheritance of the effects of use and disuse. If it be said that the experimental evidence is against this alternative, there is the work of Kammerer, which MacBride finds convincing, and there is transmission of acquired characters in bacteria (where, however, there is no "body" in the strict sense). But according to MacBride the distinction between somatoplasm and germ-plasm is a "Weismannian nightmare." The inheritance of the effects of use and disuse is *the* method of evolution, "the dominating influence which has moulded the animal world from simple beginnings into the great fabric of varied life which we see around us." J. A. T.

Mutational and "Recapitulatory" Characters. — R. Ruggles Gates (*Rep. Brit. Assoc.*, 1919, **87**, 340). A mutation is due to a chemical or physical change in a chromosome of a germ-cell, and is continued through the ontogeny by the equal splitting of the chromosomes in mitosis. What are called, not very happily, "recapitulatory" characters "arise through the impress of the environment, usually involve adaptation to new conditions, are gradually developed, and in becoming permanent involve the principal of inheritance of acquired characters. In the lengthening out of a life-cycle by the addition of adaptive larval stages there are good instances of recapitulatory characters. Such characters could not have arisen through a mutation, for that would modify every stage instead of *adding* certain stages as it does. Thus both mutational and recapitulatory characters are necessary for the phenomena of evolution. The one is nuclear in origin and centrifugal in effect; the other extrinsic in origin and ultimately centripetal in its effect in the organism." (But the transmission of an exogenous somatic modification as such or in any representative degree has not yet been proved.) J. A. T.

b. Histology.

Blood Platelets in Mammals.—A. Cesaris-Demel (*Atti. Soc. Toscana Sci. Nat.*, 1915, **30**, 156–75, 2 pls.). Blood platelets are due to megakaryocytes in the spleen which penetrate into the veins. They may also arise from megakaryocytes in the marrow. The megakaryocytes

seen in pulmonary embolism are also in the main of splenic origin, but may also come from the marrow. Besides free platelets and aggregated platelets there are other elements in the spleen, approaching the platelet type, and from these platelets may perhaps arise as well as from the megakaryocytes. J. A. T.

Eosinophilic Leucocytes in Thymus of Postnatal Pigs.—J. A. Badertscher (*Anat. Record*, 1920, **18**, 23–34). Granular eosinophilic leucocytes are formed in the thymus of the postnatal pig. It follows that the bone-marrow is not the only source of the granular leucocytes found in the blood. The fact bespeaks for the thymus a function with which it has not been generally credited. It is indicated that the lymphocytes (especially the large lymphocytes) in the thymus have, to a limited extent at least, the potentiality of the premyelocytes (myeloblast, hæmoblast, primitive blood-cell, "lymphocyte") in the bone-marrow in so far that they are capable of developing into some or all (perhaps variable in different mammalian species) of the types of the granular leucocytes found in the blood. J. A. T.

Theory of Symbions in all Cells.—Auguste Lumière (*Le Mythe des Symbiotes*, 1919, Paris, xi + 209, 50 figs.). Criticism of Portier's heresy that all the elements of Protozoa and Metazoa, and indeed practically all organisms except bacteria, contain symbiotic microbes by aid of which synthetic metabolic process is made possible. It is admitted that the normal tissues of vertebrates often contain quiescent saprophytic micro-organisms, and these have supplied in part a basis for Portier's extraordinary theory of symbions; but the microbes in question have not the qualities of Portier's "symbiotes." Mitochondria have also been mistaken for microbes, while they are only formed colloid aggregates in the cytoplasm. To suppose that vitamines are carried by special symbions is quite gratuitous. J. A. T.

Blood-coloured Muscle in Fish.—Yúzuru Okuda (*Journ. College of Agric. Imp. Univ. Tokyo*, 1919, **7**, 1–28, 1 fig.). In *Katsuwonus pelamis* and *Auxis tapeinosoma* the blood-coloured flesh in the lateral muscle (common to many fishes) contains more ether extract and less carbohydrates, soluble matter, creatine and nitrogenous matters. It is superior to the ordinary flesh in respect of its contents of phosphorus in lipoid form, but inferior in its content of phosphorus in inosinic acid form. Each kind has about the same quantity of protein-sulphur and volatile sulphur, but the red flesh has more taurine. It also has more lecithin, hæmoglobin, and hypoxanthin. Other differences are noted. J. A. T.

Cells of Tadpole's Tail.—W. J. Schmidt (*Zool. Anzeiger*, 1920, **51**, 49–63, 7 figs.). A description of (1) the ordinary pigmented epidermic cells in the outer epithelial layer, (2) the bi-nucleate strongly pigmented giant cells of the same layer, (3) the occasional ciliated cells, (4) the pigmented wandering cells which are usually found in the epithelium but sometimes in the cutis, and (5) the stellate melanophores of the

cutis. Four kinds of movement may be distinguished in these cells :—Ciliary movement, the amœboid movement of wandering cells, the irregular and regular streaming of granules—the former in the outer layer of epithelium and the latter in the melanospores of the cutis. The author points out that the tadpole's tail is admirably suited for demonstration purposes. J. A. T.

c. General.

Variation in Deer-mice.—F. B. Sumner (*Amer. Naturalist*, 1918, 177–208, 290–301, 439–54, 13 figs.). A study of the structural and pigmentary differences distinguishing four geographical races of *Peromyscus maniculatus*. The pigmentary differences show a general correlation with environmental features; the structural differences do not. All the differences are differences of degree, revealed through a comparison of mean or modal conditions rather than of individuals. These subspecific differences are hereditary. They persist when environmental conditions are interchanged. Hybrids between even the most divergent of the four races are predominantly intermediate in character, both in the F_1 and the F_2 generations. In contrast to the sensibly continuous variation and sensibly blended inheritance shown in respect to these subspecific characters is the behaviour of certain "mutations." Here are seen typical illustrations of discontinuous variation and inheritance of the strictly alternative or Mendelian type. There are two types of variation and inheritance. J. A. T.

Androgenic Origin of Horns and Antlers.—J. F. van Bemmelen (*Proc. K. Akad. Wiss. Amsterdam*, 1918, **21**, 570–5). According to Weber and others, horns and antlers were originally common to both sexes and were defensive weapons against enemies. Later on they came to be used more and more in the contests of rival males, and have become exclusively masculine features, or at least more strongly developed in the males. This is in agreement with the view of Tandler and Gross that all secondary sex features were originally specific characters. To van Bemmelen the opposite view seems more justifiable that the head armature arose in males as a means of attack in their duels for the females, and afterwards passed to the females. Among his arguments are the following :—In deer the antlers are absent in all females except the reindeer, where there may be a non-sexual function; in those antelopes that have horns in the female sex as well as in the male, the horns of the females are usually smaller, and those of the males show a tendency to hypertrophic and exaggerated growth not consistent with the requirements of practical use; similar exaggerations, e.g. the four-horned goat, are known in cattle, sheep and goats; in giraffes with small pedicle and small os cornu, the males have higher and stronger horn-stumps than the females, and they have the unpaired nasal knob; in the Okapi the horns are primarily absent in the female; the annual shedding of the antlers and their regrowth in Cervinæ are apparently connected with rut; the same appears to be the case in Antilocapra; the bony processes on the head of giraffes, Suidæ, and extinct forms cannot reasonably be regarded as practical weapons, they are far too cumbrous

and hypertrophic for that; neither can this be the case with the antlers of most deer or the horns of numerous antelopes, cattle, sheep, and goats; on the other hand the structures in question wear to a very high degree the character of sex-features, "in their exuberance, unpractical build, curious complication, obviousness and variability." But the author cannot agree with Bölsche that the growths on the roof of the skull are purely ornamental exuberances of growth, and connected with a regression of the ensiform tusks of the male. J. A. T.

Mandible of Birds.—N. G. Lebedinsky (*Revue Suisse Zool.*, 1918, **26**, 129–46, 6 figs.). A discussion of a number of points—the paired primordia of the dentary in nine orders (as in other vertebrates), the proportions of the various regions in the lower jaw, the reduction of the *pars anterior* in parrots and some other types, and the relation of particular features to the conditions of life. J. A. T.

Increasing Number of Ostrich Plumes.—J. E. Duerden (*Bull. Dept. Agric. Pretoria*, 1918, No. 7, 1–39, 12 figs.). The first-row feathers on each wing vary from 33 to 39, the mean being 36·54. The ostriches of the whole of Africa seem to produce the same average number of plumes. During fifty years of ostrich farming no advance in the number has been made. The breeding has been for quality, not quantity. Of late two 42-plumed birds have occurred. One of these survived and bred true. On the whole the wings of the ostrich have undergone degeneration as regards number of feathers. The third finger (which has no claw as is sometimes alleged) is almost buried in the flesh. The 42-plumed wing is regarded as a survivor of an ancestral condition. It appears that the factors for quantity do not interfere with those for quality. From the 42-plumed strain it may be possible to raise a stock giving the same quantity of feathers from three-quarters of the number. J. A. T.

Phylogeny of Jaw Muscles in Vertebrata.—L. A. Adams (*Ann. New York Acad. Sci.*, 1919, **28**, 51–166, 13 pls.). The two chief muscle masses of the jaw—(*a*) the adductor mass innervated by the ramus mandibularis of the fifth nerve, and (*b*) the depressor or digastric mass innervated by the facial—are homologous throughout the Vertebrata. The adductor of the fish type is the mother mass from which the muscles of mastication are derived throughout the vertebrates, by the separation of slips of this muscle and by their gradual complete separation in nerve supply through the growth of the originally small twigs into separate nerve branches. In a very interesting way the author traces the evolution of new slips, such as the so-called pterygoid muscles, and brings them into correlation with the changes in the skull, e.g. in the temporal fenestræ and the quadrate. J. A. T.

Comparative Study of Pelvic Muscles.—S. Nishi (*Arbeit. Anat. Inst. Japan, Univ. Sendai*, 1919, **3**, 1–72, 21 figs.). A study of the differentiation of muscles in the region of the exitus pelvis. Beginning with the early differentiation in the pelvic region of fishes, the author traces the differentiation of M. subvertebralis pelvus, M. obliquus pelvis, M.

rectus pelvis, which are all represented in Selachians, and those muscles of the exitus which owe their origin to the musculature of the hind limbs. The smooth musculature is also dealt with. J. A. T.

Mating in Frogs.—HAROLD CUMMINGS (*Journ. Exper. Zool.*, 1920, **30**, 325–43). Migration of frogs (of four species) into a pond at the breeding time occurs in waves, during periods of high relative humidity coincident with temperature ranging between about 41° and 52° Fahr. Voice does not direct the movements of frogs into the pond; sight is not essential for correct coupling and seems unimportant in sex recognition. Sex "recognition" in clasping results from the differential behaviour of the two sexes when clasped, and depends on the reaction of the clasping male to this differential behaviour. Clasped normal males struggle, inflate the vocal sacs and croak, and are always released.

J. A. T.

Diemyctylus viridescens with Bifurcated Tail.—BERTRAM G. SMITH (*Report Michigan Acad. Sci.*, 1913, **15**, 105, 1 fig.). A specimen with the tail forked in a vertical plane, each ramus of the forked portion having a distinct vertebral column and spinal cord. In the ventral ramus the spinal cord is not continuous with that of the dorsal ramus, but is perhaps connected with it by nerve fibres. In ordinary spina bifida the tail is divided in a horizontal plane. The condition of the specimen is probably due to an injury, followed by regeneration.

J. A. T.

Toxicity of Extract of Eel.—G. BUGLIA (*Atti Soc. Toscana Sci. Nat.*, 1919, **32**, 165–93, 2 pls.). Aqueous extract of the cutis of young stages of Anguilla has a toxic influence like that of the blood serum. The same is true of the fluid secretion of the skin in the same juvenile stages, while the larva is still transparent. J. A. T.

Spiracular Sense-Organ in Fishes.—H. W. NORRIS and SALLY P. HUGHES (*Anat. Record*, 1920, **18**, 205–9, 1 fig.). Various investigators have called attention to a sense-organ in the spiracular cleft of Elasmobranchs and Ganoids, which is probably homologous with Pinkus' organ in Dipnoi. The structures are derivatives of the lateral line system of sense-organs. The writers find on the anterior mesial wall of the spiracular cleft of *Squalus acanthias*, both embryo and adult, a tubular organ which bears one or more sense-organs. It is very variable in form and structure. In the most differentiated condition a small pore in the spiracular wall leads into a sac-like expansion with which are connected three diverticula, two short and cup-like and the third much elongate. The entire organ with its three diverticula evidently represents a much modified ampulla of Lorenzini. Its occurrence in *Mustelus* is noted. In *Raia radiata* a diverticular sense-organ opens not into the spiracle, but on the roof of the pharynx at the anterior border of the inner pharyngeal opening of the hyomandibular cleft. J. A. T.

Fish Food in the Limfjord.—P. BOYSEN JENSEN (*Rep. Danish Biol. Station*, 1920, **26**, 1–44, 4 charts). The stock of bottom animals,

serving as food for plaice and eels, varies greatly from year to year, both quantitatively and qualitatively. The bottom animals are often eaten up within the year; the brood is in many cases far from ready to replace what is devoured; different species breed in different years. In *Abra* the breeding is about every second year, in *Solen* less frequently, in *Mya truncata* only at intervals of many years. The magnitude of annual consumption in Thisted Bredning has varied between 31·8 and 84·3 gr. gross weight per square metre. The magnitude of the annual production varied (1910–1915) between 42·1 and 77·1 gr. gross weight per square metre. In *Corbula*, *Mya truncata*, and other bottom forms it looks as if the growth continued throughout life. The general result of the valuation studies is to show that an unlimited supply of fish food is not available, and that transplantation of fry is profitable only between certain limits, which in some cases have been already surpassed.

J. A. T.

Quantitative Estimate of Littoral Animals.—W. A. HERDMAN (*Journ. Linn. Soc. Zool.*, 1920, **34**, 247–59, 8 figs.). The gregarious Polychæt *Sabellaria alveolata* may show 65 to 75 tubes on a surface of about 3 square inches. Taking 65, a square foot would have 3,120, a square yard some 28,080. In many localities there are very many square yards of *Sabellaria*, therefore many millions; and these Polychæts form a favourite food of fishes like plaice and sole. A quarter of an inch square is an average size for an adult of *Balanus balanoides*, and on one square foot of rock near Port Erin 2,940 barnacles were counted. These rock-barnacles are eaten by various animals, and their larvæ form in March and April an important part of the plankton. From 80 to 100 young mussels may be counted on a square inch, which means about 129,600 on a square yard, and there are very many such square yards around our coast. "No doubt the majority of these young mussels never grow to maturity. They are killed by storms, smothered by their neighbours, or eaten by starfishes or by plaice and other fishes. In the latter case they are not lost as a food matter, and even in the former their remains will be eaten by something which will indirectly feed man. Nothing is lost in the sea, and everything ultimately in the metabolic cycle contributes to man's harvest." Of the small red Ascidian *Styelopsis grossularia* there may be 10 to 30 to the square inch, over 50,000 to the square yard. Many other interesting records are given. J. A. T.

Fauna of a Moor.—ADOLF HÆBERLI (*Rev. Suisse Zool.*, 1918, **26**, 147–231, 18 figs.). An interesting account of the fauna of a moor near Bern. The list shows 8 Flagellates (the commonest being *Phacus longicaudatus* and *Peridinium tabulatum*), 4 species of *Amœba* and *Pelomyxa binucleata*, 30 Testacea, 5 Heliozoa, 28 Ciliata, *Hydra viridissima*, 6 Turbellarians, 3 Nematodes, 5 Oligochæts, 42 Rotifers, 6 Gastrotricha, the leech *Helobdella stagnalis*, 2 Ostracods, 15 Copepods, 11 Cladocera, the Tardigrade *Macrobiotus macronyx*, 9 Hydracarina, the bivalve *Pisidium fossarium*, the Gastropods *Lymnæa peregra* and *Planorbis nitidus*, and various insect larvæ such as *Coretha plumicornis*. On many of the components of this characteristic fauna the author has interesting notes to make. J. A. T.

Tunicata.

Tadpole Larva of Amaroucium.—Caswell Grave (*Journn. Exper. Zool.*, 1920, **30**, 239–57, 4 figs.). A study of the activities and reactions of the larva of *A. pellucidum* (Leidy) form *constellatum* Verrill. The body is in constant clockwise rotation on its long axis as it is propelled through the water by the tail. The rotation is due either to the asymmetrical form of the body, or to a torsion of the tail during its strokes, or to both. Immediately after liberation they react positively to light; during the later and greater part of their free-swimming life they react negatively. At first they remain at or near the surface; later at or near the bottom. There may be a changing response to gravity; but the response to gravity is aided by the presence of directive rays of light. The viscid contents of the glandular ends of the adhesive papillæ are extruded on the outer surface of the tunic toward the close of the free-swimming period, and the initial attachment of the tadpole is due to one of these droplets coming accidentally into contact with the surface of a foreign body. The free-swimming period lasts from ten minutes to two hours. J. A. T.

INVERTEBRATA.

Mollusca.

α. Cephalopoda.

Histology of "Branchial Hearts" of Sepia. — E. Fernandez Galiano (*Boll. Soc. Españ. Hist. Nat.*, 1919, **19**, 353–81, 1 pl., 10 figs.). These enigmatical organs, situated at the base of the gills, are very vascular and likewise glandular. An account is given of their external epithelium (showing many intercellular bridges), their muscle fibres, and connective tissue network. The appendix to the so-called "branchial heart" is also described. The cortical part comprises an epithelium, a connective stroma, blood vessels, muscle-fibres and free cells. The author inclines to regard the branchial hearts and their appendices as in part pulsatile, but mainly excretory. J. A. T.

Ammonite Siphuncle.—A. E. Trueman (*Geol. Mag.*, 1920, **57**, 26–32, 2 figs.). The siphuncular tube or envelope (around the membranous siphuncle proper) is not continuous in Ammonites through all the chambers to the body chamber. In some cases the envelope did not extend through the ten chambers preceding the living chamber. This is seen in young as well as in old specimens, though the number of chambers in which there is no envelope apparently increases with the age of the individual. The author inclines to accept the suggestion of Foord and Woodward that the siphuncle was of more importance in the young animal, perhaps then serving for attachment, but that later on this function was performed by the shell muscles. It is not unlikely also that the siphuncle was of much greater importance in the early stages of Cephalopod evolution than it is in Mesozoic and recent forms. The tendency for the secretion of the siphuncular envelope in Ammonites to lag behind shell-growth suggests that the value of the siphuncle may at least have been declining. J. A. T.

γ. Gastropoda.

Relationships of the Gastropods.—LOUIS BOUTAN (*Actes Soc. Linn. Bordeaux*, 1919, **71**, 1–116, 25 figs.). There is ventral flexure in Cephalopods and Scaphopods, and dorsal flexure in Pelecypods, but nothing comparable to these in Gastropods, where there is a rotation of the anal region and of the top of the larval shell. Gastropods seem to have a monophyletic origin. Prosobranchs and Opisthobranchs show a close parallelism in their early stages and larvæ. No Gastropod is twisted on the longitudinal axis of the embryo in the cerebro-pedal region ; all except the Amphineura are twisted on the longitudinal axis of the embryo in the abdominal region. Only some are twisted on the longitudinal axis of the embryo both in the abdominal region and in the median region of the body. Those Opisthobranchs which have only a feebly developed larval shell and have in the adult state a notæum do not exhibit the torsion strictly so-called of the Prosobranchs. Those Opisthobranchs which have a shell developed like that of Prosobranchs and a cephalic disc slightly developed undergo true torsion, incompletely at first and afterwards completely. They may then have an œsophagus twisted upon itself and a Streptoneural nervous system as in Prosobranchs. The archaic forms of Opisthobranchs should be looked for among the Nudibranchs, some types of which show resemblances with Amphineura. The resemblances which Opisthobranchs with a well-developed adult shell present to Prosobranchs seem to be due to convergence, probably due to the progressive disappearance of the notæum, the progressive atrophy of the cephalic disc, and the formation of a more encumbering shell. There is no detorsion in any Prosobranch or Opisthobranch. Those, like the Nudibranchs, which are never twisted in the larval stage in the median (œsophageal) region of the body undergo no detorsion on becoming adults. Those, like some Tectibranchs, which are slightly twisted in the larval stage in the median region of the body show a slight torsion in the adult state. Those, like *Actæon*, which show complete torsion (torsion properly so-called) in the median region of the body, and become Streptoneural in the larval state, remain Streptoneural in the adult state. Finally, the Prosobranchs, which all show torsion in the strict sense, retain this in adult life in spite of all subsequent regularization of the body. The theory of detorsion has rested on a confusion between strict torsion and the general rotation of the anal region and the top of the larval shell. J. A. T.

Breeding and Habits of Periwinkle.—W. M. TATTERSALL (*Sci. Investigations Fisheries, Ireland*, 1920, **1**, 1–11, 1 pl.). The supposed eggs of *Littorina littorea* figured in Bronn's *Tierreich*, and often copied, are those of *L. obtusata*. The eggs of *L. littorea*, observed in an aquarium, are pink, enclosed in transparent capsules like a soldier's tin hat. The first ones usually contain a single egg, the later ones two or more. There is no aggregation of capsules. The eggs are laid freely on the shore and are in part borne about by the water. The same female may go on depositing eggs intermittently for a month or more (20th March to 24th April), the original act of copulation sufficing for the whole, which is roughly estimated at 5,000. Segmentation is

completed in the first day, and seems to be holoblastic. The egg hatches as an early Veliger larva, which has a prolonged free-swimming life, passing through a late Veliger stage before the adult form is reached. In *L. obtusata* the capsules are aggregated in masses, and attached to weeds; the egg hatches as a fully-formed Veliger, and the free-swimming period is thus much abbreviated. The chief food of *L. littorea* appears to be the hairs of *Fucus* and allied seaweeds ; Blegvad says it eats also animal detritus. The characteristic climbing habit has not to do with nutrition ; it is dependent on the calmness of the sea.

J. A. T.

Breeding of Cerions.—Paul Bartsch (*Dept. Mar. Biol. Carnegie Inst. Washington*, 1920, **14**, 1–55, 59 pls.). Numerous colonies of these land-snails, each with an individuality of features, occur on the Bahamas. They are nocturnal in habit, feeding on fungi, and though hermaphrodite do not reciprocally fertilize one another. A number of forms were transported to the Florida Keys, where there is a considerable variety of climate and vegetation. There is a native species, *Cerion incanum* (Binney), but it is very remote from any of the forms introduced. One of the interesting results obtained was crossing between *C. incanum* and the very different *C. viaregia*. There resulted a complex of forms in a state of flux. Had this been described by a naturalist not aware of the history it would have been described as an instance of a very variable species. But its heterogeneity was the result of the outbreeding. The inference is that similar heterogeneous colonies may be the result of outbreeding. The crossing is spoken of as having an energizing effect on the new product, but this may be the result, one would think, of the pooling of corroborative hereditary characters rather than of a physiological stimulus in the hybrid offspring. Many of the Bahama colonies illustrate the homogeneity which follows the inbreeding consequent on isolation or insolation.

J. A. T.

δ. Lamellibranchiata.

Crystalline Style in Mya arenaria.—Charles Howard Edmondson (*Journ. Exper. Zool.*, 1920, **30**, 259–91, 30 figs.). About 50 p.c. of individuals survive the extraction of the crystalline style by a severance of the style sac. A new style is formed in the proximal portion of the style sac in about 74 days when the conditions are most favourable. It is seen beginning at the end of the fourth day as a delicate sheath of mucus enclosing a core of food material, and lies on one of the typhlosoles, usually the right. It grows more rapidly in summer than in winter. Under favourable conditions a crystalline style is reformed in the short distal portion of the style sac, which is entirely separated from the proximal division by the operation. This proves that the epithelium of the style sac is the source of the crystalline style. The axillary food core disappears as the style becomes fully formed. The ingestion and digestion of food is apparently dependent upon the degree of development of the crystalline style, since not until the organ reaches a state of sufficient maturity to be projected into the stomach does the ingestion of food occur. The animal may be kept alive out of water

and without food for fourteen days after the extraction of the style. A new style begins to be formed, but it does not develop far. The typhlosoles supply the material for the substance of the crystalline style, and the shorter cells with strong cilia assist in moulding it into cylindrical form and at the same time rotate it and push it into the stomach. J. A. T.

Muscles of Bivalves.—R. ANTHONY (*Arch. Zool. Expér.*, 1919, **58**, *Notes et Revue*, 1, 1–10, 3 figs.). In the adductor muscles of Lamellibranchs there are two kinds of fibres—(*a*) smooth fibres with a high coefficient of shortening, used in slow sustained movements (the nacreous portion); and (*b*) fibres with a co-efficient of shortening not so high, associated with rapid and less sustained movements—which sometimes show distinct striations and sometimes an apparently quite different lozenge-shaped structure, occurring in many Invertebrates. According to Anthony, the fibres with the lozenge structure are fixed stages of the transition between smooth and striped muscle, and are associated with increasing rapidity of movement. This is opposed to Marceau's view, which interprets the lozenge-like pattern as due to the intercrossing of two layers of spiral fibrils. Anthony points out that the transition may be seen in one fibre, and maintains that the theory of helicoidal fibrils does not work. J. A. T.

Shell of Cockle.—C. L. WALTON (*Report Lancashire Sea-Fisheries Laboratory*, 1919, **28**, 47–50). Concentric grooves denote periods during which growth has ceased, notably winter, and their number increases in a regular manner along with the increase in the size of the shell. Variations in food supply and other environmental conditions also affect the shell. Large forms showed seven to ten grooves. There is no correlation between the number of ribs (twenty to twenty-seven) and the age and size of the shell. In the smallest specimens examined (0·98–1·50 cm. in dorso-ventral diameter) the number of ribs varied in exactly the same degree as the largest (3·50–4·11 cm.). J. A. T.

Arthropoda.

α. Insecta.

Isle of Wight Disease in Hive Bees.—JOHN RENNIE and ELSIE J. HARVEY (*Scottish Journ. Agric.*, 1919, 2, 1–13). The presence of this disease in a stock is manifested by the inability of the worker bee to fly. They loiter on the alighting board, on the ground, on grass. They gather in clusters and lie almost motionless. Individual bees, once stricken with the disease, do not recover, but a remnant of a badly affected stock was kept alive for two months in the autumn. Within the hive the smitten bees do little work, feed little, show lack of co-ordination of fore- and hind-wing, and often fall from the frames. Very generally the hind-gut becomes dilated with undischarged fæces, which is largely due to the incapacity of the bee for flight, defæcation normally occurring when on the wing. It is suggested that infection takes place most readily through contact with sick bees, in the early adult phase before

foraging. It is not certain that drones take it. The continual production of new bees may enable a stock to make good its losses from disease, but there is no recovery of sick bees nor any ultimate survival of a badly infected stock. Some other diseases may be mistaken for Isle of Wight disease. It is an infectious disease, but not causally connected with *Nosema apis*. J. A. T.

Mountain Ants of Western North America.—W. M. Wheeler (*Proc. Amer. Acad. Arts Sci.*, 1917, **52**, 457–569). Ants are specially fitted for the mapping out of geographical regions, for they are not dependent on specific food-plants; their colonies are stable and stationary entities; they are very sensitive to climatic and other environmental influences. They may ascend to a great height in their nuptial flights, but no colonies are established at high altitudes, and the wing-muscles are not capable of being used for more than a few hours after fertilization. The author has made a study of the conditions of humidity (warmth, slope exposure, steepness, and so on) that determine the distribution of mountain ants, and has analysed the characteristics of various ant faunas in North America. J. A. T.

The Argentine Ant in Madeira.—M. C. Grabham (*Rep. British Assoc.*, 1919, **87**, 209). Insidiously introduced into Madeira, *Iridomyrmex humilis* has suppressed competing species, has established destructive colonies up to 2,500 ft. above sea level, has ruined coffee cultivation, many fruit trees (*Citrus* especially), and crops of sweet potatoes (*Batatus*), and has invaded every house. There is no winter weather to check the increase. Poultry, young birds, and bees are defenceless. The ants are ingenious and persistent in food-searching. They transplant the pupæ to favourable conditions. They make bridges to reach flies caught on sticky fly-paper. The females are mostly impregnated within the formicary and immediately afterwards shed their wings. There is great harmony in working, and there is a singular absence of fighting when separate communities meet. The ant's enemies are few. Spiders devour them; and one spider in particular, *Pholcus phalangioides*, is very formidable. Chalk powder is a useful counteractive, and banding with rags soaked in corrosive sublimate. A circle of powdered potassium cyanide round one lemon tree killed all the comers and goers, and showed that 40,500 ants had been tending the scale-insects on this one tree. The ant appears to be as serious a pest as Colorado beetle or cotton-boll weevil. One hope is in eventual exhaustion and decreased fertility. J. A. T.

Australian Cerapachyini.—W. M. Wheeler (*Proc. Amer. Acad. Arts Sci.*, 1918, **53**, 215–65, 17 figs.). The Cerapachyini are of unusual interest to the myrmecologist, because they represent one of the most primitive sections of the most primitive sub-family of ants, the Ponerinæ, and because they are so closely related to the sub-family Dorylinæ as to suggest that the latter must have arisen from Cerapachyine ancestors. They form small colonies, like most Ponerinæ. The species of *Eusphinctus* (with the probable exception of *E. turneri*) are hypogæic in habits, a peculiarity also indicated by the absence of eyes in the

workers of nearly all the species and the small eyes of the females. The large-eyed members of the genus *Phyracaces* forage in troops (or in whole colonies ?) on the surface of the ground, their prey consisting of the brood of other ants. The workers of the Cerapachyini are easily recognized by their long, slender, jointed bodies ; the petiole and post-petiole of the abdomen are distinct; and in *Eusphinctus* even the gastric segments are marked off from one another by pronounced constrictions.
J. A. T.

Ants of Borneo.—W. M. Wheeler (*Bull. Mus. Comp. Zool. Harvard*, 1919, **63**, 43–147). A list of 256 Bornean species is given, adding 58 to the known fauna, and 23 new to science. On the whole, the fauna has many forms in common with Sumatra, Java, and the Malay Peninsula, but many seem to be peculiarly Bornean. "Of course, Borneo has been invaded by the usual tropicopolitan tramp species." But the most interesting fact is that the series of Bornean genera comprises, especially in the mountains, several of ancient aspect, like *Cerapachys*, *Phyracaces*, *Metapone*, *Dimorphomyrmex*, *Gesomyrmex*, *Echinopla*. Several, like *Gesomyrmex chaperi*, are probably relicts of the once very widely distributed Eocene ant fauna. J. A. T.

Frit-Fly on Oats.—T. H. Taylor (*Pamphlets Agric. Dept. Univ. Leeds*, 1918, **108**, 1–12, 12 figs.). A finely illustrated account of this serious pest. Shining black flies, less than ⅛th of an inch, appear in May and June. After mating, the females lay their eggs upon the young corn between the lowermost sheaths. The white egg is a mere speck to the naked eye. The female has a retractile egg-laying tube. The hatched larvæ cut a short spiral track through the intervening leaves, attack the growing point, and pupate in the recesses of the plant. The flies of the summer brood emerge in July or the beginning of August, and lay eggs upon belated tillers, or more especially on young ears, the eggs being usually placed on the inner surface of the chaff. The larvæ pupate in the grain, and a third brood emerges during August and September. These lay in a winter cereal or on a grass. The larvæ, feeding through the winter on the grass shoots, pupate in April or May, and give rise to the first brood of flies of the new season. The larvæ only live through the winter. In spring and summer the life-history takes about thirty-five days. Death occurs after egg-laying. Frit-flies are conspicuous chiefly on sunny days, when they seek the tops of plants. They move in a leisurely way, occasionally taking short flights from one leaf to another. It is probable that frit-flies, like many other insects which lay their eggs separately, spend a considerable time over the process and require to feed. They are unusually wary and shy when laying their eggs. J. A. T.

Urticating Hairs of Parasa lepida.—P. E. Keuchenius (*Tijdschr. Nederland. Dierk. Ver.*, 1916, **15**, 94–109, 1 pl., 1 fig.). It is well known that the setæ of some caterpillars, like *Thaumatopœa*, the Procession Caterpillar, produce great skin irritation. The author has studied the urticating setæ of a Javanese caterpillar, *Parasa lepida*. There is considerable variety, and a description is given of : (*a*) delicate

pointed setæ, each containing, enclosed in a fold of epithelium, a single glandular cell with a large branched nucleus; (*b*) flagelliform setæ; (*c*) flask-shaped and conical setæ; and (*d*) branched setæ, in which the glandular cell is at its simplest. It is probable enough that the glandular cell which fills most of the epithelium-lined cavity of the urticating seta is of epidermic origin, like the epithelium itself. In its young stage the glandular cell is in communication with the epithelium and the epidermis by means of protoplasmic threads. The author notes that we are not yet quite certain whether the hairs of the Procession Caterpillar are glandular or not. J. A. T.

Vitality and Longevity of Silkworm Moths during Cold and Rainy Season.—MAUDE L. CLEGHORN (*Journ. and Proc. Asiatic Soc. Bengal*, 1919, **15**, 101–5, 3 plates of tables). On the whole the moths live very long during the cold seasons, fairly long in the hot weather, but only a few days in the rainy season. There is always a pronounced rise in the vitality of the moths in the cold season, and a fairly sudden drop in the rainy season. J. A. T.

Metamorphosis of Lepidoptera.—EDNA MOSHER (*Bull. Illinois State Lab. Nat. Hist.*, 1916, **12**, 17–159, 9 pls.). Including a good account of the changes preceding pupation. The first striking difference between larva and pupa is the diminution of size in the latter, which is especially associated with the reduction of the alimentary canal. The absence of legs is only apparent; the scars of the pro-legs remain; so do indications of the larval setæ. The full-grown larva usually hastens to pupate. The larval cuticle becomes wrinkled; the moulting glands pour their secretions between the outer and inner layers of the cuticle. The old cuticle is loosened off and splits along the middle line of the thorax, and is worked towards the tail-end. The liberated pupa is covered with a very thin cuticle. In the genus *Micropteryx* the appendages of the pupa are all movable, and so are all but the posterior segments of the abdomen. In ordinary cases the appendages are soldered to each other, and in the more specialized forms to the body surface as well. The mobility of the abdominal segments is reduced to nil. Before the emergence of the imago the individual appendages usually get free. In more specialized forms the hard pupal cuticle remains in one piece, except for the slit through which the imago emerges. In the highly-specialized Lepidoptera the appendages are not fully formed when pupation takes place, but consists of the transparent cuticular coverings through which one or more slender tracheæ may be seen. Before the pupa covering is cast the cuticular parts of the adult are fully formed in what is sometimes called the pre-imago stage.

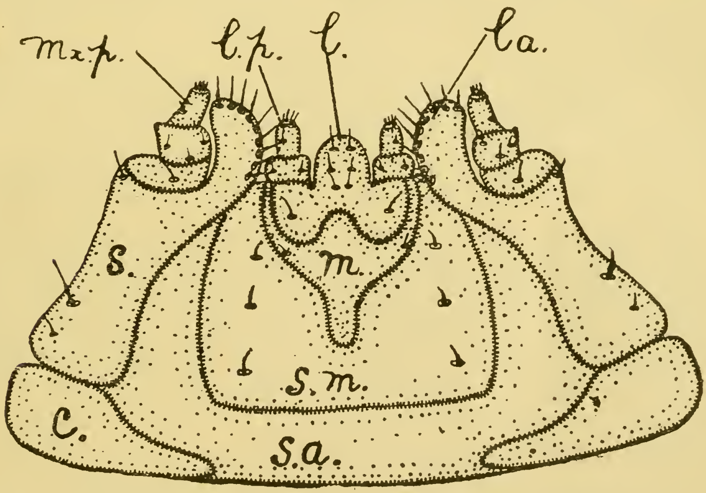
J. A. T.

Classification of Lepidoptera based on Pupal Characters.—EDNA MOSHER (*Bull. Illinois State Lab. Nat. Hist.*, 1916, **12**, 17–150, 9 pls.). It is shown that the following pupal characters may be used to good effect in the determining phylogeny:—The number of movable segments, the freedom of the appendages, the number of sutures present in the

head, the relative length of the body segments, the presence or absence of visible labial palps and maxillary palps, the presence of exposed portions of the prothoracic femora in specialized pupæ, and the method of dehiscence. J. A. T.

Markings of Lepidopterous Pupæ.—J. F. VAN BEMMELEN (*Proc. K. Akad. Wetensch. Amsterdam*, 1918, **21**, 1–10). According to the author the colour-markings of butterfly pupæ—those on the body as well as those on the wing-sheaths—are to be regarded as an original pattern, the uniform colour of the white, yellow, brown or black pupæ of most moths resulting from the loss of the primitive design. Theories of sympathetic coloration and influence of surroundings are not necessary to explain the manifestation of the pattern. It is not denied, however, that modifications of the pattern may secondarily come to have some protective value. J. A. T.

Structure and Habits of Cryphalus abietis.—WALTER RITCHIE (*Ann. Applied Biol.*, 1919, **5**, 171–99, 15 figs.). A description of this wood-boring Scolytid beetle, and a contrast between it and *C. piceæ*; an



First maxillæ and labium of larva of *Chryphalus abietis*.
Greatly magnified.

c., cardo; *s.*, stipes; *mx.p.*, maxillary palp; *la.*, lacinial lobe; l., ligulæ; *l.p.*, labial palp; *m.*, mentum; *s.m.*, sub-mentum; *s.a.*, sub-mental area.

account also of the larva and pupa, of the brood-galleries, and of the internal reproductive organs. There are excellent figures. The larvæ are destroyed in numbers by a Chalcid parasite. The parent beetle makes a circular burrow round the base of a branch, and the larval galleries radiate out on all sides almost at right angles. The parent beetles do not all die after egg-laying, but in many cases feed anew prior to a possible second egg-laying. J. A. T.

Study of Setal Pattern of Caterpillars and Pupæ.—A. Schierbeek (*Tijdschr. Nederland. Dierk. Ver.*, 1917, **15**, 261–418, 5 pls.). A wide study of caterpillars and pupæ has led the author to the following conclusions:—The modern architecture of the insect's thorax is quite secondary. The anal segments vary considerably in number in different species. To begin with all the abdominal segments bore a pair of legs. The various types of setal arrangement, for which a new nomenclature is proposed, can be derived from each other. A metamerically repeated pattern of pigment spots is more primitive than a pattern of stripes. The change of setæ into verrucæ is a reversible process. The pupa and the first caterpillar instar are both primitive, while the other larval instars are to be considered as secondary adaptations. The pupa is to be regarded as a sub-imaginal stage which has become secondarily stationary. The various types of caterpillars have for the most part evolved independently of or parallel to one another. A general larval pattern for the Holometabola is still uncertain. J. A. T.

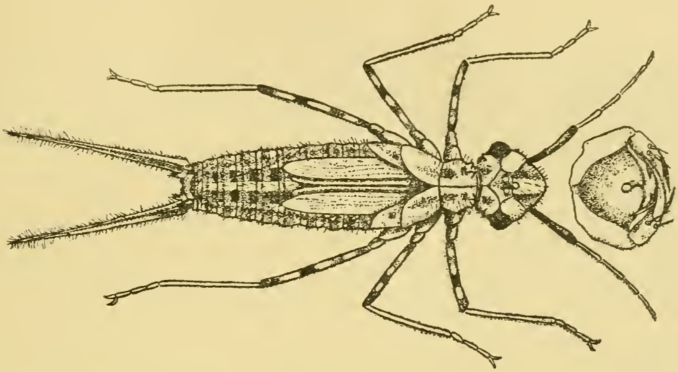
Bacterial Disease of Larvæ of June Beetle.—Z. Northrup (*Rep. Michigan Acad. Sci.*, 1913, **15**, 64). The grubs of the June beetle (*Lachnosterna* sp.), which do serious damage to crops, were found infected by a *Micrococcus* which blackened the tissues. Healthy larvæ placed in inoculated soil were quickly infected, especially if a cut was made in the integument. The disease was transmitted to *Allorhina nitida*, another June beetle, and to the cockroach. It may turn out to be useful as a remedial measure. Rabbits and guinea-pigs are immune.
J. A. T.

Muscid Larva sucking Blood of Nestlings.—O. E. Plath (*Publications Univ. California, Zoology*, 1919, **19**, 191–200). Evidence of nestling birds (*Astragalinus*, *Zonotrichia*, etc.) being sucked and weakened or killed by larvæ of *Protocalliphora azurea* (Fallen). The larvæ were gorged with blood, which is stored in a diverticulum of the œsophagus just behind the pharynx. Pupation occurs in the fæces at the bottom of the nest. Some blood seems to be necessary if the larvæ are to reach maturity. Forty-four nests infested with larvæ of *P. azurea* (and *P. chrysorrhœa*) have been recorded. J. A. T.

Chromosomes in Larva of Corethra plumicornis.—Armand Dehorne (*Arch. Zool. Expér.*, 1919, **58**, *Notes et Revue*, pp. 25–30, 10 figs.). The somatic cells show three chromosomes, which seems to be the diploid number. The smallness of the number is remarkable, and the fact that it is an odd number. How the meiotic division is accomplished has not been observed as yet. The material is well suited for the study of mitosis. J. A. T.

Larva of Micrometrus lineatus.—F. C. Fraser (*Records Indian Museum*, 1919, **16**, 197–8, 1 pl.). This dragon-fly larva from Poona lives in quickly running water, holding on tightly to roots, submerged twigs and the like. They are difficult to collect because they grip

firmly and because they accumulate debris on the short hairs which cover the abdomen and caudal appendages. They are rectal breathers. No true or functional caudal gills are present, these being replaced by two



Larva of *Micrometrus lineatus*, with the mask shown on the right.

caudal appendages which seem only to serve for defence. These parts are readily surrendered by autotomy, as is probably the case in the related Rhinocyphine larva. The " mask " is long and narrow.

J. A. T.

British Orthoptera.—W. J. Lucas (*A Monograph of the British Orthoptera*, Ray Society, 1920, 1–264, 25 pls., 25 figs.). The author is to be congratulated on the completion of this very welcome monograph, which deals with thirty-one indigenous species and eight naturalized aliens. The sub-orders include the earwigs, the cockroaches, the crickets, the long-horned grasshoppers and the short-horned grasshoppers. The workmanship of the monograph is at a high level, and there is a generous supply of illustrations. J. A. T.

δ. Arachnida.

Sarcoptid Mite in a Cat.—Harold Cummings (*Report Michigan Acad. Sci.*, 1913, **15**, 106). Note of occurrence of *Notoedres cati* Hering, heavily infesting a cat at Ann Arbor, and causing loss of hair over a large surface. The genus includes Sarcoptid mites infecting cats and rabbits, but there seem to be few records of their distribution.

J. A. T.

Pygidium of Trilobites.—P. E. Raymond (*Geol. Mag.*, 1920, **57**, 22–5). The large pygidium is primitive and the small one is specialized. The thorax grows through the degeneration of the pygidium, new segments being pushed forward through the pygidium by those which are added in the growing area immediately in front of the anal segment. The free segments of the thorax become such by the breaking down of a large pygidium, and a small pygidium is the result of the degeneration

of a large one. The large primary pygidium was probably, as Spencer suggested, of use as a caudal fin in swimming. Perhaps the group had a pelagic rather than a benthonic origin. J. A. T.

ε. Crustacea.

Life-history of Cape Crawfish.—J. D. F. Gilchrist (*Journ. Linn. Soc. Zool.*, 1920, **34**, 189–201, 2 pls., 13 figs.). The embryonic development of *Jasus lalandii* remains unknown, but the naupliosoma stage and the phyllosoma have been observed. The transition from the phyllosoma to the puerulus is not known, but the pueruli have been followed to the post-puerular stage. The red spots on the underside of the puerulus disappear and all the upper parts become coloured; the spines of the carapace, definite in number in the puerulus, become much more numerous; there are changes in antennules, mandibles and some other appendages; the exopodites of the pereiopods disappear; the cervical groove is well marked; the telson has additional spines; and so on. The post-puerulus differs from succeeding stages in having the cuticle uncalcified, in having the incisor part of the mandible provided with denticles on the margin of its thick cuticle, in showing no sex differentiation in the pleopods, and in the third maxillipedes being separate at their bases. J. A. T.

Species of Asellus.—E. G. Racovitza (*Arch. Zool. Expér.*, 1919, **58**, Notes et Revue, 31–43, 12 figs.). It appears that *Asellus aquaticus* auct. is a taxonomic error which has lasted for nearly two centuries. Under this name there are ranked a medley of different forms, of diverse origin and taxonomic value, but not forming one species. The author differentiates a northern species *Asellus aquaticus* Linné and an older species *A. meridianus* of more southern distribution. J. A. T.

Study of Asellus.—E. G. Racovitza (*Arch. Zool. Expér.*, 1919, **58**, Notes et Revue, 49–77, 38 figs.). A minute discussion of *Asellus coxalis* sp. n. (Syrian), *A. coxalis peyerimhoffi* subsp. n. (Algerian), and *A. banyulensis* (France), which in respect to several important structures form a very definite orthogenetic series. The origin of the stock may be looked for in Asia Minor, whence it has spread along the southern shores of the Mediterranean. Attention is also directed to the sex dimorphism and to the abundance of a large commensal protozoon, *Stylocometes digitatus* Cl. and L., on the endopodites of the pleopods. J. A. T.

Studies on Asellidæ.—E. G. Racovitza (*Arch. Zool. Expér.*, 1920, **58**, Notes et Revue, 79–115, 33 figs.). A detailed discussion of the first and second pleopods in Asellidæ, which have come to be associated with reproduction and have undergone reductions and transformations. In the male the first pleopod is reduced to two undivided joints, a sympodite and an exopodite; it is absent in the female. In the male the second pleopod shows an undivided sympodite, a slightly modified

two-jointed exopodite, and an endopodite, biarticulate or undivided, transformed into a copulatory organ. It is reduced to one piece (fused sympodite and exopodite) in the female. There is also a discussion of *Asellus communis*. J. A. T.

Sex-intergrade Strain of Cladocera.—ARTHUR M. BANTA (*Proc. Soc. Exper. Biol. Medicine*, 1916, **14**, 3–4). After 130 parthenogenetic generations of *Simocephalus vetulus*, in the course of which only females occurred, there being no males nor sexual eggs, the 131st generation showed, in addition to normal females, both males and many sorts of sex intergrades. "There occurs practically every gradation from the entirely normal female with a full complement of female secondary sex characters ; through female intergrades of all sorts ; hermaphrodites, with various combinations of secondary sex characters; and male intergrades of various rank ; to normal males with all the primary and secondary sex characters distinctly and strongly male." J. A. T.

Sex Intergrades in Cladocera.—ARTHUR M. BANTA (*Proc. Nat. Acad. Sci.*, 1918, 373–9). Unmistakable intermediate sex forms are known in Riddle's hybrid pigeons, Goldschmidt's hybrid gipsy moths, and Banta's Cladocera. They are not sex mosaics but sex intergrades. In *Simocephalus vetulus* the occurrence of clearly marked sex intergrades is rare ; it is not so unusual in *Daphnia longispina*, where several strains have been studied. In these, however, male sex intergrades (i.e. intergrades with testes) are almost or quite lacking, and males are rare, whereas in the *Simocephalus vetulus* sex intergrade stock normal males are abundant and male intergrades are common. Sex intergrade production would seem to be the result of a disturbed balance, a condition which is a struggle of two nearly equal factors or sets of factors, the one making for maleness, the other for femaleness. The result of this struggle of factors is the development of individuals ostensibly male in part and female in part, and obviously intermediate in part—but as a whole distinctly intermediate in sex characters. The facts suggest that maleness and femaleness are not complete and mutually exclusive states, but that sex is relative. J. A. T.

Selection with a Pure Line of Cladocera.—ARTHUR M. BANTA (*Proc. Soc. Exper. Biol. Medicine*, 1919, **16**, 123–4). A study of long-continued selection upon several parthenogenetic pure lines (clones) of three species of Cladocera, using their reactiveness to light as a basis for selection. In most of the lines the results, though suggestive, are inconclusive ; or there is clearly no effect of selection ; or (in two lines) the results even suggest slight differences in the reverse of an effect of selection. But with one line of *Simocephalus vetulus* the result of selection was pronounced and convincing. This line was subjected to selection for a period of 54 months, covering 181 generations of descent. In the final ten generations the strain selected for greater reactiveness to light had a reaction time less than one-third as large as that for the strain of the same line selected for reduced reactiveness to light.

J. A. T.

Cave Ostracods.—Paul Paris (*Arch. Zool. Expér.*, 1920, **58**, 475–87, 4 pls.). Not many Ostracods are known from caves, but that is in part because it is difficult to capture these minute animals. A description is given of *Candona breuili* sp. n. and *Sphæromicola topsenti* Paris. The latter lives in commensalism with a cave Isopod, *Cæcosphæroma burgundum* (and probably on *C. virei*), sheltering on the ventral surface near the head, and hanging on very firmly. It seems to reproduce all the year round. It cannot live away from the Isopod, but it is no parasite. A detailed account is given of the appendages of both species. J. A. T.

Annulata.

Madagascar Polychæts.—P. Fauvel (*Arch. Zool. Expér.*, 1919, **58**, 315–473, 3 pls.). An account of a large collection, representative of twenty-three families, and including nine new species. In *Lumbriconereis papillifera* sp. n. there are large elongated vesicles, below and behind the parapodia, which represent long nephridial ampullæ. In *Gravierella multiannulata* g. et sp. n. there is a very remarkable intercalary growth with unique peculiarities. The anal cone is at the base of a dilated funnel. J. A. T.

Vitelline Membrane of Serpulids.—A. Soulier (*Arch. Zool. Expér.*, 1916, **56**, *Notes et Revue*, 16–20). The vitelline membrane disappears in the course of development. In *Serpula crater* it disappears from off the trochophore cells which it protects, but it disappears quite gradually, beginning at the posterior end, where the larva grows in length. It is much the same in *Hydroides pectinata* and *Protula meilhaci*, where the disappearance is again posterior. The cuticle is an epidermic formation, and the idea that the vitelline membrane is transformed into the cuticle is not to be entertained. J. A. T.

Australian Exogoneæ.—W. A. Haswell (*Journ. Linn. Soc. Zool.*, 1920, **34**, 217–45, 2 pls., 2 figs.). Descriptions of Australian representatives of this Polychæt family, including *Exogone fustifera* sp. n., *Grubea pusilloides* sp. n. It is demonstrated that the pedal glands produce the secretion by means of which the ova are attached after extrusion. A description is given of the proventriculus with its non-striated muscle-columns, and of the hitherto undescribed glands, the ducts of which open into it. An account is given of the changes undergone by the nephridia of both sexes of *Exogone* in association with the development of the sex-cells. In *Grubea pusilloides* there is distinct hermaphroditism. The author also describes some stages in the development not previously investigated. J. A. T.

Nematohelminthes.

Syngamus laryngeus in Indian Cattle.—A. L. Sheather and A. W. Shilston (*Bull. Agric. Research Pusa*, 1920, No. **92**, 1–8, 28 figs.). This parasite was found in about 13 p.c. of 700 buffaloes and hill bulls and in about 15 p.c. of 100 plains cattle. With few

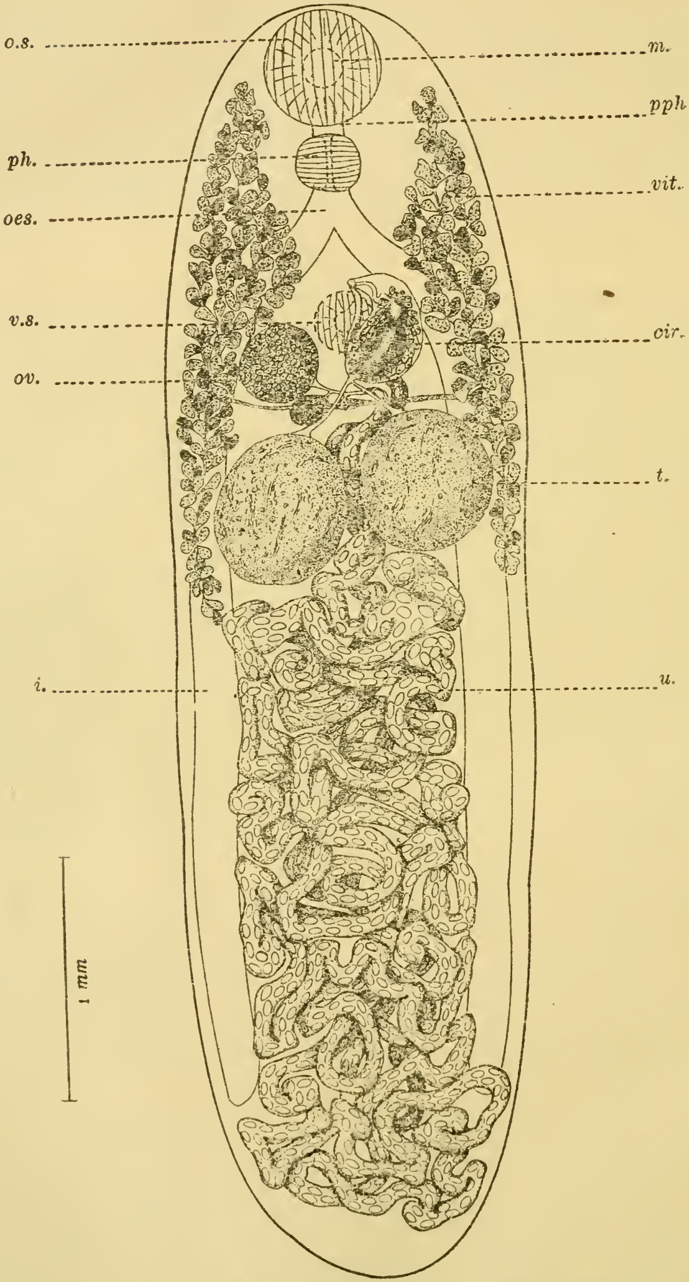
exceptions they occurred in the larynx. In no case were the males and females found apart. An account is given of the general structure of both sexes. Except in one special case no pathogenic effects could be traced to the parasite. It seems that the eggs are passed out under the posterior flap of the saddle-shaped pouch of the male embracing the flattened boss on the body of the female on which the vulva opens. For it appears very wasteful that the eggs should only escape, as is usually supposed to be the case in *S. trachealis*, by the bursting of the female worm. J. A. T.

Platyhelminthes.

Head-generation in Planarians.—C. M. CHILD (*Journ. Exper. Zool.*, 1920, **30**, 403–18, 3 figs.). Isolated pieces of *Planaria dorotocephala* do not always show uniform reconstitution or regeneration. The structures produced at the anterior ends of pieces show a graded series from normal heads to headless healing of the wound. Five types have been distinguished—normal, normal but teratophthalmic, teratomorphic with more marked inhibition of the median region, anophthalmic without eye-spots, and acephalic with a mere healing of the wound and no outgrowth. The term "head-frequency" is used to indicate the frequency with which these different types of anterior end occur in a given set of pieces. Head-frequency in the regeneration of pieces is lower in physiologically younger (smaller) than in physiologically older (larger) animals. Head-frequency is lower in pieces from starved than in pieces from well-fed animals, even when the two are of the same size. Head-frequency is higher in pieces which are frequently stimulated to motor activity during at least several hours after section than in pieces remaining undisturbed. The range of head forms is the same in relation both to physiological conditions and to external chemical and physical agents, and the changes produced are changes in the frequency of the different forms. This non-specific effect of both physiological and external factors indicate that the action of these factors is essentially quantitative. J. A. T.

New Japanese Polyclads.—MEGUMI YERI and TOKIÖ KABURAKI (*Annot. Zool. Japon.*, 1920, **9**, 591–8, 5 figs.). A description of *Neostylochus fulvopunctatus* g. et sp. n., near *Stylochus*, with oval body, no tentacles, marginal eyes confined to the frontal margin, true seminal vesicles, prostate dorsal to seminal vesicle, slender tubular penis, and large single accessory vesicle to the vagina. There is also an account of *Prosthiostomum trilineatum* sp. n., differing widely from other species in its coloration. J. A. T.

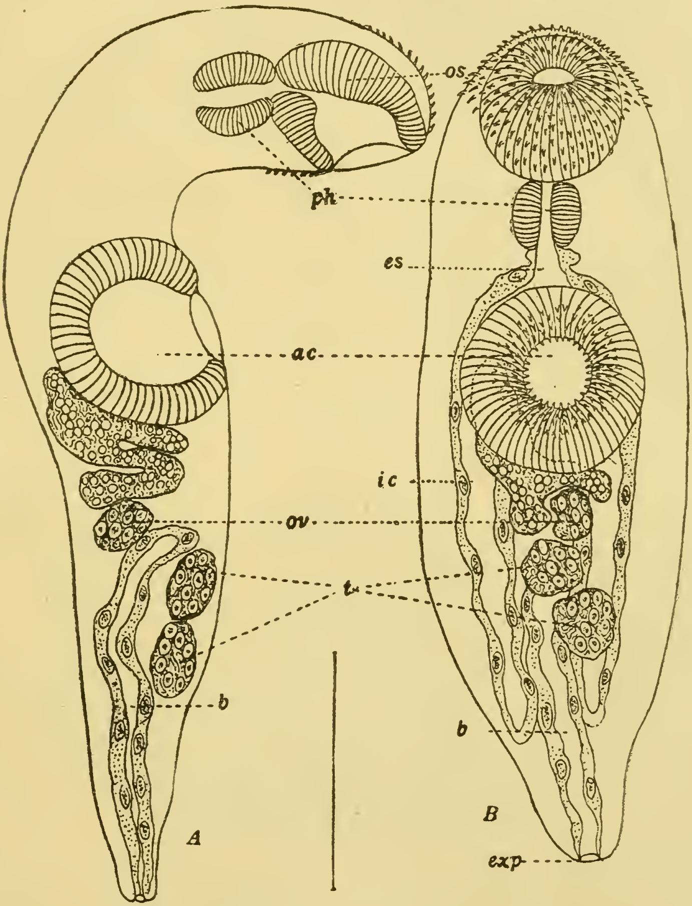
New Distome from Rana aurora.—W. W. CORT (*Publications Univ. California, Zoology*, 1919, **19**, 283–98, 5 figs.). In the intestine of the red-legged frog, in fourteen cases out of thirty, a new Distome was found, *Margeana californiensis* g. et sp. n., 2·4–5 mm. in length. It shows the characters of the sub-family Brachycœliinæ; digestive system with prepharynx, short œsophagus, and intestinal cæca extending into the posterior fifth of the body, but not reaching the posterior end; excretory system of the "2–6–3" type, with a club-shaped bladder; vitellaria



Dorsal view of *Margeana californiensis*, slightly compressed.
cir., cirrus sac ; *œs.*, œsophagus ; *i.*, intestinal cæcum ; *m.*, mouth ; *o.s.*, oral sucker ; *ov.*, ovary ; *ph.*, pharynx ; *pph.*, prepharynx ; *t.*, testis ; *u.*, uterus ; *vit.*, vitellaria ; *v.s.*, ventral sucker

extending from in front of the pharynx to the posterior limits of the testes; cirrus sac large; testes large, filling most of the width of the body. Affinities are with the genus *Brachycœlium*. J. A. T.

New Cercaria from North America.—W. W. Cort (*Journ. Parasitology*, 1918, 5, 86–91, 1 pl., 1 fig.). In *Planorbis companulatus*



Cercariæum mutabile. Scale equals 0·1 mm.

A, side view; B, ventral view; *o.s.*, oral sucker; *ph.*, pharynx; *ac.*, acetabulum; *ov.*, ovary; *t.*, testes; *b.*, excretory bladder; *œs.*, œsophagus; *exp.*, excretory pore.

smithii Baker, from Douglas Lake, Michigan, there was found a new Cercaria, provisionally named *Cercariæum mutabile*. The rediæ filled the liver of the snail. The adult is not known, but the structure of the Cercaria suggests the sub-family Allocreadiinæ. The Cercaria has

practically no adaptive larval characters, and a considerable development of adult characters. This is evidently correlated with the omission of the free-swimming stage of the life-history. The excretory system consists of a simple club-shaped bladder, a series of collecting tubes, and sixty-four flame cells, with their capillaries arranged in eight groups of four on each side." J. A. T.

Adaptability of Schistosome Larvæ to New Hosts.—W. W. CORT (*Journ. Parasitology*, 1918, **4**, 171–3). In many cases, e.g. *Fasciola hepatica*, the larvæ of Trematodes can flourish in species which are not their normal specific hosts. The larvæ of *Schistosoma hæmatobium* are known from *Bullinus contortus*, *B. dybowski*, *Physopsis africana*; the larvæ of *Schistosoma mansoni* is known from *Planorbis boissyi* and *P. guadelupensis*. Other examples are given of lack of specificity in the choice of intermediate host. Thus among fork-tailed Cercariæ *Cercaria douthitti* Cort from *Lymnæa reflexa* has been found in *L. stagnalis oppressa*, *L. stagnalis perampla*, and *Physa ancillaria parkeri*; and an undescribed species from Douglas Lake was found in three genera—*Planorbis trivolvis*, *Lymnæa exilis*, and *Physa ancillaria*. The question of the adaptability of the schistosomes to new intermediate hosts becomes a problem of great significance in relation to the spread of schistosomiasis. J. A. T.

Bryozoa.

New Japanese Polyzoa.—YAICHIRÔ OKADA (*Annot. Zool. Japon.*, 1920, **9**, 613–34, 1 pl., 7 figs.). A report on thirteen (five new) species of *Retepora* (including *Reteporella*) and two species of *Adeonella*, with figures of the minute structure of zoœcia, operculum, and the "mandibles" of the avicularia. J. A. T.

Echinoderma.

Double Hydrocœle in Sea-urchin Larvæ.—E. W. MACBRIDE (*Rep. British Assoc.*, 1919, **87**, 207–8). When plutei of *Echinus miliaris* are transferred at an age of three days to sea-water, the salinity of which has been increased by adding 2 grm. of NaCl per litre, left there for a week, and then re-transferred to ordinary sea-water, they show at the age of about twenty-one days in a certain percentage of cases (not more than 5 p.c.) two hydrocœles. It is suggested that the exposure to hypertonic water acts on a hidden rudiment in the larva and starts the right hydrocœle developing. It has been previously shown by the author that the organs developing on one side of the larva tend to inhibit the development of similar organs on the other side. So, when the proper hydrocœle on the left side begins developing and gets a long start over its right antimere, it may check and eventually entirely suppress the development of this. The re-transference to normal sea-water may possibly hold up temporarily the exuberance of development of the left side and allow the right side to hold its own. "If this supposition be well founded, echinoderm development would afford a striking instance of that 'struggle between the parts' on which Roux has always insisted as an important feature in development." J. A. T.

Appearance of Division Spindle in Sea-urchin Ova.—L. V. HEILBRUNN (*Journ. Exper. Zool.*, 1920, **30**, 211–37). During the period between fertilization and the first cleavage of the sea-urchin egg the viscosity of the cytoplasm rises until it reaches a maximum, then it decreases again. Similar changes occur in relation to the second cleavage. The changes in viscosity are very marked and indicate the occurrence of a gelation in the cytoplasm. This reaches its height just before the spindle appears; later on the cytoplasm becomes more fluid again. The gelation is a predetermining factor in spindle or aster formation; if it is suppressed the mitotic figure does not form. Such suppression can be produced by fourteen different substances, all lipoid solvents; it can also be produced by cold. Although effecting the same result, the actions of cold and of lipoid solvents are mutually antagonistic. The effect of hypertonic solutions on dividing eggs may be interpreted as due to an increase of the cytoplasmic viscosity. Potassium cyanide and chloretone also act in this way. The cytoplasmic gelation which occurs in relation to mitosis is apparently due to an abstraction of water, for it can be most closely imitated by an abstraction of water, and entrance of water into the fertilized egg reverses the normal cytoplasmic gelation.

J. A. T.

Complete and Functional Hermaphroditism in a Sea Urchin.—MAURICE HERLANT (*Arch. Zool. Expér.*, 1918, **57**, *Notes et Revue*, 28–31, 1 fig.). In *Paracentrotus lividus* hermaphroditism was observed,

Section of hermaphrodite gonad showing large oogonia and numerous minute sperm-cells.

a very rare occurrence. It has been noted by Viguier in *Sphærechinus granularis*. The specimen showed three normal testes, an atrophied testis, and a mixed gonad with both ova and spermatozoa. Autogamy was effected artificially, and could no doubt occur in nature. Accidental hermaphroditism has been recorded in *Asterias glacialis*. In *Asterina gibbosa* it is known that the young individuals are males and become female. Giard has described a similar condition in *Echinocardium cordatum*.

J. A. T.

Cœlentera.

Structure of Favia.—George Matthai (*Brit. Antarctic "Terra Nova" Exped., Zoology*, 1919, 5, 69–96, 4 pls., 2 figs.). In Astræidæ the formation of colonies takes place by extra-tentacular and intra-tentacular budding—i.e. by the formation of new stomodæa, hence of buds, outside or inside the tentacular rings of older polyps. In both cases new stomodæa arise afresh in diverticula by invagination of the oral disc or by union of the margins of the broader mesenteries, without involving the longitudinal fission of existing stomodæa. In *Favia* colony-formation is mainly by intra-tentacular budding, but extra-tentacular budding unaccompanied by bilateral and hexameral symmetry occurs at the growing edges of colonies. A description is given of the corallum and polyps of *Favia conferta*, which is compared in detail with *F. fragum*. A survey is taken of the Atlantic species. J. A. T.

West African Antipatharians.—Hjalmar Broch (*Antipatharia*, 1920, 18–22, 2 figs.). Little is known of Antipatharians from West African waters. A description is given of *Antipathes* (?) *spinescens* Gray and *Stichopathes* (?) *occidentalis* (Gray) Brook. The dubiety refers to the absence of polyps. Attention is directed to fragments of a very large form with a sinuous main axis (1½ cm. in diameter), few lateral branches, and almost vestigial spines. The form suggests Roule's *Antipathes grimaldii*. J. A. T.

Leptogorgia irramosa (Grieg).—Arvid R. Molander (*Arkiv f. Zool.*, 1919, 12, No. 5, 1–7, 2 figs.). A revision of this species (= *Gorgonia pinnata*). The main stem is not prominent; the branching is irregular; the polyps are about 2 mm. long, and irregularly or alternatively disposed on the stem and branches; the calyx is usually distinct and about 1 mm. high; the cœnenchyma includes spindles and double stars; the polyps show spindles which form eight longitudinal double rows near the base of the tentacles. The description and photograph given do not convince the recorder that *L. irramosa* is a *Leptogorgia* at all, for members of this genus are marked by minute double spindles and the verrucæ are typically low and inconspicuous. The suggestion that *Stenogorgia* and *Callistephanus* may be included in the genus *Leptogorgia* does not seem to the recorder to be warranted.
J. A. T.

Hydroids of Ingolf Expedition.—Hjalmar Broch (*Danish Ingolf Expedition*, 1918, 5, 1–205, 1 pl., 1 chart, 95 figs.). The thecaphore hydroids fall into four main groups or series of families, the most primitive being the Hebellina with conical proboscis and homogeneous gastral endoderm. From this are derived the Haleciina and Sertulariina, with the gastral endoderm not homogeneous. An exceptional position is that of the Proboscoida with club-shaped proboscis. The author gives an account of a large collection including two new genera, Nemertesia and Nematocarpus, and some new species. To the athecate forms previously dealt with is added *Branchiocerianthus reniformis* sp. n. A zoogeographical survey is taken of the Hydroid Fauna of the North

Atlantic. The interest of the large memoir is mainly systematic, but the introductory chapter proposing a classification based on the characters of the nutritive polyps is of wider interest. J. A. T.

Asexual Multiplication of Microhydra ryderi.—A. Goette (*Zool. Anzeiger*, 1920, **51**, 71–7, 8 figs.). The frustules of this polyp are true buds, which are separated off from the mother-animal by a process of division. The longitudinal division which separates off a frustule-primordium, and the transverse division by which the two halves of the laterally fixed frustule are separated from one another, are conditioned by a divergent growth-movement and a divergent correlation. J. A. T.

Protozoa.

Crystalloids of Entamœba histolytica.—Armand Dehorne (*Arch. Zool. Expér.*, 1919, **58**, *Notes et Revue*, 11–8, 4 figs.). In this Amœba, associated with abscesses of the liver, there are abundant spindle-shaped crystalloids which appear in vacuoles in the endoplasm. They correspond to chromidia. The crystalloids are ephemeral; they disappear or are much reduced when the cyst-envelope is formed. Protozoa with shells or capable of forming cysts have an important chromidial apparatus, and this is causally related to forming the shell or cyst. The crystalloids represent a stage in the metabolism that leads to shell-making. Perhaps trichocysts are similarly related to membrane-making. Perhaps every chromidial apparatus has this significance. J. A. T.

Nucleoplasmic Relations in Arcella.—R. W. Hegner (*Journ. Exper. Zool.*, 1920, **30**, 1–96, 47 figs.). The data gathered from a study of four species favour the hypothesis that there is normally a definite quantitative relation between nucleus and cytoplasm. In both binucleate and multinucleate specimens the nuclei, although free to move about in the cytoplasmic mass, become arranged in such a manner that they are equidistant from one another, and hence have each an equal amount of cytoplasm with which to interact. Many micro-vivisection experiments bear out the idea of a constant mass relation between cytoplasm and nucleus. An excess in the amount of cytoplasm in proportion to nucleoplasm appears to be dangerous. The final conclusion of an important investigation is that the size of the organism and the characteristics correlated with size are dependent upon the chromatin mass; that changes in these characters are not due to cytoplasmic nor chromidial influence, but to qualitatively unequal nuclear divisions, resulting in two types of daughter nuclei differing in the determiners that control the growth of the chromatin; and that other characters that vary independently must be controlled by other determiners within the nuclei. J. A. T.

Chilomastix mesnili of Man.—Charles A. Kofoid and Olive Swezy (*Univ. California Publications, Zoology*, 1920, 117–44, 3 pls., 2 figs.). In the human intestine this is a common and widely distributed parasite often mixed up with *Trichomonas* and other forms. It has a deep spiral groove running posteriorly from right over to left as a permanent cell-organ distinct from but adjacent to the cytostome. It

persists in the cyst stage as a meridional structure. The neuromotor apparatus consists of centresome, nuclear rhizoplast, three blepharoplasts

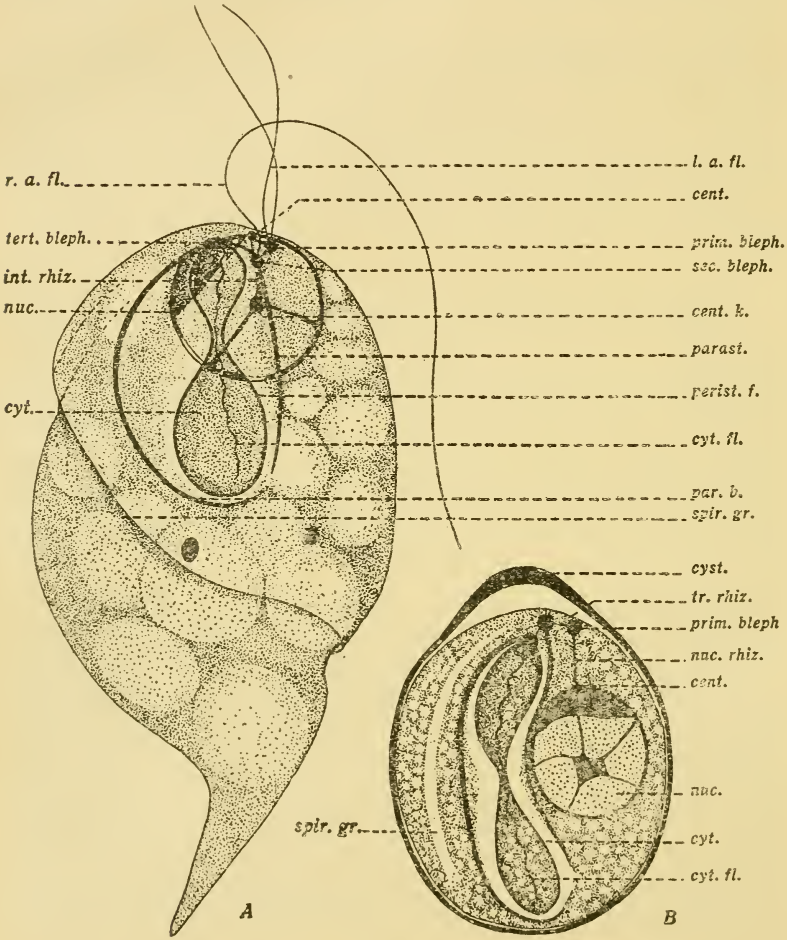


Fig. A.—*Chilomastix mesnili* (Wenyon). Normal flagellate viewed from the ventral or oral side and showing all the structures of the body. × 6370.

Fig. B.—The cyst viewed from the ventral or oral side. × 6370.

cent., centrosome; *cent.k.*, central karyosome: *cyst.*, cyst wall; *cyt.*, cytostome; *cyt.fl.*, cytostomal flagellum or undulating membrane; *int.rhiz.*, intranuclear rhizoplast; *l.a.fl.*, left anterior flagella; *nuc.*, nucleus; *nuc.rhiz.*, nuclear rhizoplast; *par.b.*, parabasal body; *parast.*, parastyle; *perist.f.*, peristomal fibre; *prim.bleph.*, primary blepharoplast; *r.a.fl.*, right anterior flagellum; *sec.bleph.*, secondary blepharoplast; *spir.gr.*, spiral groove; *tert.bleph.*, tertiary blepharoplast; *tr.rhiz.*, transverse rhizoplast.

and connecting rhizoplasts, the primary giving rise to two flagella, the secondary to one and to the parastyle, the tertiary to the parabasal, the peristomal fibril, and the cytostomal flagellum or undulating membrane. The centroblepharoplast complex is thus subdivided into four granules, the centrosome and three blepharoplasts having continuous rhizoplast connexions with the central karyosome of the nucleus. The nucleus is polarized with the centrosome anterior and the spireme forms in its longitudinal axis. Binary fission in the cyst is morphologically longitudinal. The blepharoplast-rhizoplast chain splits lengthwise at mitosis, and the remainder of the neuromotor complex appears to be produced *de novo* by outgrowths from the blepharoplasts prior to the spireme stage. The daughter centrosomes are connected by a paradesmose. In mitosis the nuclear membrane remains intact and its constriction is spatially transverse. The daughter nuclei are for a time connected by the paradesmose, but lie at opposite poles of the cyst, but may later change their position. The neuromotor system of *Chilomastix* is strikingly similar to that of the right half of *Giardia* in symmetry and in its constituent elements. The two daughter individuals are each equivalent to the right half of *Giardia*. The bilateral symmetry of the two-celled *Giardia* could arise only by a complete morphological reversal from the sinistral to the dextral type of one of the two daughter schizonts at mitosis. The genus *Chilomastix* is closely related in the structure to the bilateral binucleate Hexamitidæ and may be their source. J. A. T.

Sensibility of Volvox to Light.—HENRY LAURENS and HENRY D. HOOKER, Jun. (*Journ. Exper. Zool.*, 1920, **30**, 345–68, 2 figs.). A determination of the relative stimulating effect of radiation in different parts of the spectrum. The sensibility of Volvox to radiation of different wave-lengths but of equal energy (sensibility to radiation at equal energy) was investigated by two methods: (*a*) the relative duration of the presentation time, and (*b*) the relative rate of locomotion and precision of orientation. Both methods showed that a particular wave-length has the highest stimulating value. The necessity of using an equal-energy spectrum for such work is emphasized. J. A. T.

Double Forms of an Amicronucleate Oxytricha.—J. A. DAWSON (*Journ. Exper. Zool.*, 1920, **30**, 129–57, 22 figs.). In cultures of an amicronucleate race of *Oxytricha hymenostoma*, under conditions similar to those in which syngamy usually takes place in hypotrichous forms, there is a strong tendency for the formation of double animals, or "twins," by plastogamic dorsal fusion. Twins have all the structures possessed by two single animals. They reproduce, giving (*a*) two pairs of twins exactly similar to the parent; (*b*) from the anterior portion, a twin which pulls apart to form two single animals, and from the posterior portion, a typical twin; (*c*) from the anterior portion, two typical single animals, and from the posterior portion, a typical twin. Twins may form from normal strains, from descendants of single animals arising from twins, and from the progeny of cannibal animals. In stock and mass cultures they do not survive in competition with single individuals;

they require favourable environment. A pedigreed strain has been bred for 102 generations. By selection a striking increase in the percentage of twins may be produced. The division rate is similar to that of normal single animals. As pairing, cannibalism, and twin-formation occur among animals in a similar physiological condition, it is believed that the three phenomena are but expressions of an abortive attempt to undergo syngamy, abortive probably because of the absence of idiochromatin morphologically segregated as nuclei. J. A. T.

Life-History of Myxidium gadi.—JIVOIN GEORGEVITCH (*Arch. Zool. Expér.*, 1919, **58**, 251–89, 3 pls., 3 figs.). Monosporic, disporic, and polysporic forms occur. In all cases, however, the scheme of the life-history is the same. At the end of sporulation a syncarion is formed, and this unicellular stage (zygote or pansporoblast resulting from the total union of two isogametes) is at the start of each new developmental cycle. This zygote does not immediately enter upon sporulation; it passes through several generations of similar schizonts before becoming sporont. There is always alternation of generations between schizogonic forms and sexual sporogony. Schizogony is marked by equal cell-divisions; in sporogony there are two unequal divisions of the nucleus alongside of equal divisions. After several generations of schizogony, the details of which are described, the schizonts enter into sporogony. If the schizont is monosporic or disporic, the first division of its nucleus is unequal, unlike the subsequent divisions. If it is polysporic all the divisions are equal. The diverse phases of the monosporic, disporic, and polysporic operations are dealt with, all of them leading eventually to a zygote. At no stage are these parasites intracellular. J. A. T.

BOTANY.

GENERAL,

Including the Anatomy and Physiology of Seed Plants.

Cytology,

Including Cell-Contents.

Chromosomes in Zea Maïs—Y. KUWADA (*Journ. Coll. Sci. Tokio*, 1919, **39**, *Art.* 10, 1–148, 2 pls.). A paper dealing with the number and individuality of the chromosomes in *Zea Maïs*, and with the origin of this species. The author finds that the number varies from ten to twenty; plants which may be regarded as the ancestors of this species, and those which are nearly related, also usually have twenty chromosomes in the cells of the root-tips. In a few species of sugar-maize the number of chromosomes varies with the different species; in the root-tips examined they varied between twenty and twenty-four. There appears to be no relation between the number of chromosomes and the chemical constitution of the endosperm. Comparative examination of the number, size and length of the chromosomes in the root-tip proves that increase in the number is the result of transverse division of the chromosomes. The dissimilarity in these respects in the component chromosomes seems to confirm Collins's opinion that *Z. Maïs* is a hybrid between *Euchlæna* and an unknown plant belonging to the Andropogoneæ. Three kinds of chromosomes are characteristic of the species:—(1) Long, with a tendency to divide transversely, derived from the *Euchlæna* ancestor; (2) shorter, with no such tendency, derived from the *Andropogon* ancestor; (3) chromosomes found in certain species in which the transverse division has become a fixed hereditary character. The chromosomes which split or tend to split are dominant to those which do not split, but the dominance is an unstable factor. The different combinations of these three kinds of chromosomes cause a variation of the number within certain limits, and result in two kinds of gametes, one of which is characterized by a constant number of chromosomes, and another in which the number is variable. The size of the nucleus and of the cell are dependent upon the size of the chromosomes, and conversely the chromosomes themselves vary with the size of the cell.

S. G.

Crystals in Australian Timbers.—R. T. BAKER (*Journ. Proc. Roy. Soc. N.S. Wales*, 1918, **51**, 435–44, 9 pls.). The writer has examined specimens of timber belonging to twenty-two families, and finds that fifteen of them contained crystals in the secondary wood. The crystals were so numerous and well-defined that it was possible to determine their crystalline system without any special preparation or breaking down of the wood. They were usually contained "in a specialized form of chambered wood-parenchyma, with partitions dividing it

into cells of about equal size containing as a rule an individual crystal." In one specimen, *Mallotus philippinensis*, the ray-parenchyma contained as many as four crystals in one cell. The micro-sections were immersed in strong hydrofluoric acid without any effect upon the crystals, except in the case of *Strychnos arborea*, where they occur in great numbers in special long pockets; in this case the greater part of the crystals disappeared. In *Eucalyptus pilularis* and *Tristania conferta* the "grit" proved to be silica. The author finds no support for the theory that crystals are characteristic of certain families or genera, since there is great uniformity in those found in all Australian timbers, the only variation being in size and number. S. G.

Structure and Development.

Vegetative.

Fibro-vascular Formations in Monocotyledons.—A. DAUPHINÉ (*Ann. Sci. Natur. Paris*, 1917, **20**, 309–14, 1 pl.). A study of the development of the "supplementary" fibro-vascular formations in *Dracæna indivisa* and in *D. Draco*, in order to discover their relationship to the secondary tissues of Dicotyledons. The author refers to the marked similarity between the mode of secondary thickening in the Chenopodiaceæ, and in such Monocotyledons as *Dracæna*. He compares with the latter the formation of successive new generative layers in the beet, showing that in this case the only real difference is that in *Dracæna* the generative layer does not pass between the bundles. He also shows that the greater part of the elements regarded as primary in Dicotyledons really arise from secondary tissues. On the other hand, the alternate primitive phase is found to be suppressed in Monocotyledons owing to acceleration of development; the normal generative layer has such a brief duration of function that the elements beyond the primary bundles are forced to assume the functions of the generative layer. Finally, he finds a general unity of plan in the evolution of the conducting apparatus of both Monocotyledons and Dicotyledons, which bridges over the division formerly placed between the two groups. S. G.

Growth of Trees.—A. MALLOCK (*Proc. Roy. Soc.*, Ser. B., 1919, **90**, 186–99, 6 figs., 4 diagrams) has adapted the method employed for observing the extension of cracks in buildings to finding the rate of growth of timber-trees. This method depends upon the production of bands of light, as a consequence of the illumination of sheets or prisms of glass meeting at definite angles. By suitable means the shifting of $\frac{1}{10}$th of a band can be noted, and this corresponds to the extension of $\frac{1}{1000000}$th of an inch of growth. The writer made observations day and night on four trees between June 21 and the end of July, and found that increase of girth was closely related to temperature; growth was most rapid when the temperature was at its lowest. Rain produces great effect, even a shower resulting in an increase of girth. The effect of rain may be partly mechanical, being the result of the swelling of the bark, but the checking of evaporation from the leaves appears to be an important factor. In these experiments there was no means of

measuring the humidity of the air, which would seem to be of considerable importance in causing increase of growth. The method of measurement appears to be simple and satisfactory, and therefore suitable to further observations along the same lines. S. G.

CRYPTOGAMS.

Pteridophyta.

External Morphology of the Stems of Calamites, with a Revision of the British Species of Calamophloios and Dictyocalamites of Upper Carboniferous Age.—E. A. Newell Arber and F. W. Lawfield (*Journ. Linn. Soc.*, 1920, **44**, 507–30, 3 pls.). An account of the external features of *Calamites* stems. As compared with fossilized pith casts, the external casts or impressions are rare and have often been confused with pith casts. The features of pith casts are their nodes and their ridged and grooved internodes; and there may be infranodal canals and branch scars. Submedullary casts are frequent, representing a region within the secondary wood; they are characterized by very broad ribs (medullary rays) and the absence of infranodal scars. External casts show the following characters: nodes, internodes (smooth, striated, etc.), leaf scars, branch scars, root scars, which are discussed in detail. An attempt is made to correlate the specimens of British *Calamites* which show external surfaces with their corresponding pith casts. And this is followed by a systematic revision of the British species of *Calamophloios* and *Dictyocalamites*. A. Gepp.

Physiological Anatomy of Xerophytic Selaginellas.—J. C. Th. Uphof (*New Phytologist*, 1920, **19**, 101–31, 12 figs.). Six p.c. of the species of *Selaginella* are xerophytic. In the xerophytic species the dorsal and ventral leaves are closely approximated, and exhibit a striking similarity of size—a matter of much importance, since the ventral leaves contain but few chloroplasts, the work of photosynthesis devolving upon the comparatively large dorsal leaves. The hygrophytic species on the other hand have their leaves spaced out, and show a marked difference in size between the dorsal and ventral leaves. There are three groups of xerophytic *Selaginellas*:—1. Plants with vertical leaves of the same shape and size; the apex of each leaf ends in a long awn containing no chloroplasts; the anatomical construction is sclerotic. 2. Plants with slender, wiry, trailing stems, spreading over the ground or hanging from rocks and sometimes trees. 3. Plants with a spreading habit, often forming a flat, dense and close rosette, rolling into a cluster-ball during drought. In the first group the erect leaves form a protection against intense insolation. The growing points of the stem receive the sun's rays directly, but the apical bundle of awns reflects the light entirely. The epidermis, hypodermis and outer cortex are thick-walled and heavily impregnated with suberin. The elements of the protoxylem and metaxylem are much narrower than in hygrophytic species. Some species are petrophilous, some are psammophilous. The second group comprises straggling plants, less sclerotic than the previous group, but very thick-walled. Some have a red pigment in very exposed stems;

and some have very narrow xylem vessels, the water-supply being slight and the leaves very small. The mesophyll is well developed and possesses large air-spaces. The plants of the third group are very well fitted for a semi-arid environment, being densely ramified and curling up into a close cluster; the leaves are placed horizontally on both sides of the stem. The anatomical construction of all species shows a rather thin-walled hypodermis and cortex on the upper (inner) surface of the stem, and thick-walled on the lower (outer) surface. During drought the thin-walled tissue loses water more quickly than the thick-walled; hence the plant curls inward. Reopening is due to quicker absorption of water by the thin-walled tissues; and the plants may increase in weight by 42–54 p.c. A considerable amount of oil is found in the cells, in the form of small drops in the protoplasm; these oil-drops unite and grow larger during desiccation, and possibly form a protecting film around the protoplasm. Hygrophytic species produce no oil, but starch; and it may be that the oil is a reserve food in the xerophytic species, which produce less starch. A. G.

Bulbils of Lycopodium lucidulum.—R. WILSON SMITH (*Bot. Gazette*, 1920, **69**, 426–37, figs.). A description of the bulbils found on certain non-strobiliferous species of *Lycopodium*. The author concludes that (1) the bulbil is not the homologue of a branch, since it has only a simple vascular strand and not a complex exarch radial system: nor is it a reduced dichotomy, nor equivalent to the bulblets of *Lilium* or *Allium*. (2) It is not the homologue of a sporangium, because *inter alia* it differs in receiving a prominent vascular strand. (3) It is a transformed leaf, retaining the position, dorsiventrality, and in a great measure the vascular strand of a leaf; it may perhaps be homologized with an early undeveloped bulblet of a fern. Further, the author describes the origin and vascular bundles of the branches, leaves and bulbils. He ascribes the accumulation of starch in the bulbil proper to the absence of phloem in the narrow neck joining it to the base, and the detachment of the ripe bulbil to the disorganization of the xylem walls in this region. The rate of growth he estimated from the persistent bases of the bulbils; and he gives some observations on the habits of the plant. A. G.

Bryophyta.

Cytology of Bryophyta. I. Spore-formation in Chiloscyphus polyanthus.—RUDOLF FLORIN (*Arkiv för Botanik*, 1919, **15**, No. 16, 1 pl.). An account of spore-formation in *Chiloscyphus polyanthus*, describing and figuring the presynaptic stage, the strepsinema, diakinesis, metaphase, anaphase, etc. A. G.

North American Species of Asterella.—ALEXANDER W. EVANS (*Contrib. U.S. Nat. Herb. Washington*, 1920, **20**, 247–312). A monograph of the North American members of this difficult genus, the name of which has been involved in much change and confusion. *Asterella* Pal. de Beauv. was created in 1805–6 for two of Linnæus's species, *Marchantia tenella* and *M. hemisphærica*. These have long been

separated under two different genera—as *Reboulia* (originally *Rebouillia*) *hemisphærica* Raddi (1818), and *Fimbriaria* (originally spelled *Fimbraria*) *tenella* Nees (1820). The name *Asterella tenella* should be restored; but strangely enough S. O. Lindberg (1868) revived *Asterella* for *A. hemisphærica*, while Trevisan (1874), in ignorance of this, revived *Asterella* for *A. tenella* with five other species, but soon afterwards (1877) adopted Lindberg's definition of *Asterella* and revived Corda's *Hypenantron* for *A. tenella* and its allies. Lindberg at the same time also changed and accepted Trevisan's definition of *Asterella* for *A. tenella* and its allies. Le Jolis (1895) ridiculed this confusion and advocated the suppression of *Asterella*. But, by the rules, *Asterella* must stand, though most authors have preferred to use *Fimbriaria*. The number of species in the genus is now about ninety-seven. A chapter is devoted to the morphological features of the plant. Detailed descriptions of the fifteen North American species (three are new to science) are given, with synonymy, distribution, and critical notes. And a most helpful key to the species is provided. A. G.

Three South American Species of Asterella.—ALEXANDER W. EVANS (*Bull. Torrey Bot. Club*, 1920, **46**, 469–80). Detailed descriptions of three species of *Asterella*, which are restricted to Chili, Ecuador and Bolivia respectively; six other species have been recorded for the continent, two of which are extensions from North America. A. G.

Notes on North American Hepaticæ. VIII.—ALEXANDER W. EVANS (*Bryologist*, 1919, **22**, 54–73, 1 pl. and figs.). Critical notices of ten species of Hepaticæ, especially *Corsinia coriandrina* (Spreng.) Lindb., *Petalophyllum Ralfsii* (Wils.) Nees & Gottsche, *Nardia fossombronioides* (Aust.) Lind., *N. rubra* (Gottsche) Evans, *N. subelliptica* Lindb., some of which are discussed at considerable length and figured. A. G.

Notes on New England Hepaticæ. XV.—ALEXANDER W. EVANS (*Rhodora*, 1919, **21**, 149–69, 1 pl. and figs.). *Nardia hyalina* (Lyell) Carringt., *N. obscura* (a new species) and *N. obovata* (Nees) Lindb. are described and discussed in detail. A. G.

New Riccia from Peru.—ALEXANDER W. EVANS (*Torreya*, 1919, **19**, 85–8, 1 fig.). *Riccia bistriata*, a new species collected at Santa Ana, in Peru, by O. F. Cook and G. B. Gilbert in 1915, is characterized by a feature not known elsewhere in Marchantiales—namely, parallel pairs of thickening-bands running vertically down the sides of the columns of cells which form the green assimilative tissue of the thallus. A. G.

Notes on North American Sphagnum. VIII.—A. LEROY ANDREWS (*Bryologist*, 1919, **22**, 45–9). A continuation of the monograph of the section Cuspidata, containing critical notes on *Sphagnum tenellum*, *S. cuspidatum* and its var. *Torreyi*, and incidentally on some allied species. A. G.

Ecological Succession of Mosses.—ARAVILLA M. TAYLOR (*Bot. Gaz.*, 1920, **69**, 449–91, 2 figs.). A discussion of the moss ecology of

the Chicago region, under two headings—xerarch and hydrarch successions. In Table I. is shown the succession of the fifteen principal mosses present in the xerarch series of the sand dunes, through the five stages—cotton-wood, pine, transition pine-oak, oak, beech-maple. Table II. represents the hydrarch succession from open water of lagoons and ponds, through the stages—sedge mat, tamaracks, swamp forest, to the beech-maple forest; and here twenty mosses are concerned. In the successions on sand, mosses are most abundant in number and quantity in the pine stage and decrease in and after the oak stage. In the hydrarch successions the greatest dominance of mosses is usually in the swamp or bog forest (tamaracks). Mosses are important pioneers on bare rock surfaces, and continue abundant far into the forest association. They are of the greatest value from an economic standpoint. They are soil-formers and provide favourable habitats for germination of higher plants. They assist largely in forming the surface mat over deep lakes and in filling up shallow waters. They may help to build up tufa, and to make floating islands. They conserve moisture and give it out slowly, thus checking the formation of disastrous floods. They prevent erosion of clay or sand surfaces. A. G.

Hymenostomum in North America. — A. LeRoy Andrews (*Bryologist*, 1920, **23**, 28–31). A discussion of the delimitation of the genus. There is a perplexing group of closely related species which have been divided among the genera *Astomum*, *Hymenostomum* and *Weisia*. Alike in their gametophytes and with sporophytes representing a very close gradation of forms, these plants make the limitation of species and genera a matter of debate. *Hymenostomum rostellatum* is as good an *Astomum* as a *Hymenostomum*. After citing instances of confusion, natural affinities, attempted revisions of genera, he proposes to retain the name *Hymenostomum* for the group, the type being *H. microstomum* (Hedw.) R. Br., and to employ three sub-genera—*Astomum*, *Euhymenostomum*, *Weisia*, which normally are respectively cleistocarpous, hymenostomous and peristomate. A. G.

New and Interesting South African Mosses.—H. N. Dixon (*Trans. Roy. Soc. South Africa*, 1920, **8**. 179–224, 2 pls.). An account of a large number of mosses from South Africa collected mainly by H. A. Wager, T. R. Sim, J. Henderson, including about two dozen species new to science, and valuable critical notes on many species which required illumination—e.g. *Campylopus inchangæ*, the specific name of which has been rendered by various authors as *Inczangæ*, *Incrangæ*, *Incrangæ*, *Imerangæ*. It is shown that the water moss *Fissidens julianus* is a widely distributed species, and that *F. Berterii*, *F. Dillenii* (both from temperate South America), *F. capensis* and *F. Muelleri* (Australia) cannot be separated from it. In half a dozen other cases the identity of Cape species with previously described European species is demonstrated. A. G.

Mosses of Madeira.—A Luisier (*Broteria*, 1919, **17**, 28–66, 1 pl.). Continuation of an historical and systematic account of the moss-flora of Madeira, with some critical notes, descriptions and a few figures. A. G.

Moss Exchange Club.—*Twenty-fifth Annual Report.* (York: Coultas and Volans, 1920, 255–66.) A list of the British and foreign mosses and hepatics collected and distributed by the members of the club, with critical notes on the more interesting specimens. A. G.

Thallophyta.

Algæ.

Auxospore-formation of Chætoceros debile Cleve.—K. YENDO and J. IKARI (*Bot. Mag. Tokyo*, 1918, **32**, 145–9, 1 pl.). Auxospore-formation has been observed in about 20 out of the 160 genera of diatoms. It has been previously described in *Chætoceras* by Schütt and others, and the present authors give a detailed account of the process in *C. debile*, which they had the chance of observing on a free scale near Oshoro. A. G.

Diatomaceous Earth of Lompoc, Santa Barbara Co., California.—N. YERMOLOFF (*Geolog. Mag.*, 1920, **57**, 271–7). The siliceous remains in the fossil deposit of Lompoc belong to two main and dominating groups of organisms, Dictyochidæ and Diatomaceæ. The diatoms are all pelagic and nearly all discoid, with only a very few gonoid forms. They are all undoubtedly northern forms; indeed, very similar to those usually common in European seas. The author discusses the composition of the deposit in detail, noting the presence or absence of certain genera and species. The predominating genera are *Euodia*, *Coscinodiscus* and *Thalassionema*, together with the silico-flagellate *Dictyocha*, and these give to the deposit its characteristic facies. Of the nine groups of *Coscinodiscus* only five are represented in Lompoc; the constituent species of these groups are analysed and discussed. Finally, an enumeration is given of all the species recorded. E. S. GEPP.

Rare Species of North American Diatomaceæ.—C. S. BOYER (*Bull. Torr. Bot. Club*, 1920, **47**, 67–72, 1 pl.). Descriptions of eleven new species, and of *Navicula Attwoodii* Perag., which is here figured for the first time. Abnormal forms of *Aulacodiscus oregonus* are discussed and compared, and it is suggested that these specimens may be evidences of the formation of gonidia. Numerous valves occur in rich gatherings much smaller than the normal valve and of uniform size, equal to that of the partially formed valves in the specimen figured. In each of the specimens examined the internal finely granular plate is distinctly shown, but its function in the formation of new valves is problematical. E. S. G.

Fresh-water Diatoms from Iceland.—ERNST ØSTRUP (*The Botany of Iceland: Copenhagen, J. Frimodt: London: J. Wheldon*, 1920, **2**, Part I., 1–98, 5 pls.). A posthumous paper based upon 572 samples of diatom material collected by various hands in several parts of Iceland. The work is divided into two parts:—1. A systematic list containing references to literature and descriptions of 57 new species and 13 varieties, which are all figured in the plates. 2. An alphabetical list of the 468

forms, with tables showing their distribution in Iceland itself and their wider distribution in the Arctic region and in the five continents of the world. As the number of forms previously recorded for the island was 131, the result of the author's work is to make the total about 3½ times as large. Appended is a list of the forms found in hot springs, and mostly in the living state; these represent 178 species and varieties, and 31 genera. A. G.

Photosynthesis in Fresh-water Algæ.—B. Moore and T. A. Webster (*Proc. Roy. Soc.*, Ser. B., 1920, **91**, 201–15). A discussion of the fixation of both carbon and nitrogen from the atmosphere by green plant cells, to form organic tissue. Experiments show that in the absence of all sources of nitrogen, save the atmosphere, unicellular algæ can, in presence of abundant CO_2, fix N, grow and form proteins; but the rate of fixation and growth is much accelerated if nitrites or oxides of nitrogen are available. Such oxides of nitrogen occur normally in pure country air, especially in spring and summer. Formaldehyde and methylic alcohol—products of photosynthesis—are very poisonous to the green cell; but when extremely diluted they are found, in the absence of CO_2, to be nutritious to the cell. A. G.

Review of the Genus Chlorochytrium.—B. M. Bristol (*Journ. Linn. Soc.*, 1920, **45**, 1–28, 3 pls., 1 fig. in text). In an historical introduction the author recalls the work of Prof. G. S. West in submerging six other genera into *Chlorochytrium*, and his suggestion that similar drastic revision was needed for the species of the genus. She shows that certain characters used for the limitation of the species are too variable to have specific value. These are the shapes of the cells, the nature and extent of the thickenings of the cell-walls, the form and size of the chromatophore, and the fusion or asexual development of the zoogonidia. Thus she has been able to reduce the number of species to ten, and of each of these she gives a full and critical account, with varieties. This is followed by a summary of the species with synonyms, references to literature, diagnosis and habitat. Three doubtful species are shortly described, which in the absence of authentic material are impossible to identify. Finally, a note is added on *C. glœophilum* Bohlin, which is probably only a form of *C. Facciolaæ* Bristol. The plates represent preparations of *C. Lemnæ* and *C. paradoxum*. E. S. G.

Studies on the Chloroplasts of Desmids. IV.—Nellie Carter (*Annals of Botany*, 1920, **34**, 303–20, 3 pls.). The first part treats of the chloroplasts of *Staurastrum*. Mostly these are axile; only in *S. tumidum* were they found to be parietal. Many of the smaller species have a simple axile chloroplast consisting of a central axis which contains a single pyrenoid and a bilobed mass projecting into each angle of the semi-cell. Amongst the larger species the general form of the chromatophore is often quite similar to that of the smaller ones, but there are variations in the number of plates in each angle and also in the number and arrangement of the pyrenoids. Most of the species examined had one point of pyrenoid formation in the centre of the

semi-cell, but in a few species the pyrenoids occur either in the angles only or else in addition to those in the centre. *S. brasiliense* and *S. grande* differ from most of the other species examined in their very numerous pyrenoids. In *S. grande* also some individuals show a tendency to the parietal disposition of the chloroplast by the total disappearance of the axis in the centre of the semi-cell, leaving the peripheral lobes of the chloroplast isolated.

The second part of the paper discusses the behaviour of the chloroplasts during cell-division. Those of *Netrium* and *Cylindrocystis* probably behave much as do those of *Closterium*, as described by Lutman. In all the Placoderm Desmids examined the process of cell-division is rather different from that of the Saccodermæ. The nucleus of the cell completes its division, and the two new colourless semi-cells can readily be distinguished before there are any visible changes in the chromatophores. The latter then rapidly stream through the isthmus from the old semi-cell into the new one, so that by the time it is fully formed it is usually uniformly green. The process is completed by the division of the chloroplasts at the isthmus of each individual. In those species in which the points at which pyrenoids may occur are fixed the young semi-cell is provided with a corresponding number of pyrenoids by the budding of those already existing in the old semi-cell. Where the pyrenoids are indefinite in number and scattered, a number of these enter new semi-cells together with the budding chromatophore. A striking feature of the ingrowth of the chloroplast in many species is the rapidity with which the cell-wall of the young semi-cell is completely mantled by the chloroplast, often at the expense of the more central parts of the semi-cell. This phenomenon is responsible for the formation of parietal chloroplasts in isolated specimens of species which normally possess axile ones, and probably also for their original production in species in which they have been permanently acquired. A. G.

Fresh-water Algæ from Santo Paulo.—O. Borge (*Ark. Botanik*, 1919, **15**, No. 13, 1–108, 8 pls.). The algæ here recorded were collected by Dr. Löfgren and sent to Prof. Nordstedt, who has published a certain number of them in Wittrock and Nordstedt's "Exsiccatæ." Most of the Oedogoniaceæ have been published in Hirn's monograph. The collection was afterwards handed over to the author for further investigation, and the publication of figures. Nearly 400 species and numerous varieties are enumerated; and 27 new species and several varieties are described in the present paper. E. S. G.

Sub-Antarctic and Antarctic Marine Algæ. III. Chlorophyceæ.—D. E. Hylmö (*Wissensch. Ergebn. Schwedisch. Südpolarexped.*, 1901–3, Band IV, lief. 16, *Stockholm*, 1919, 20 pp., 36 figs.). A report of the marine Chlorophyceæ collected by Dr. Skottsberg on the coasts of Tierra del Fuego, Graham's Land, S. Georgia, and the Falklands. To each species is appended a list of synonymy and bibliography, geographical distribution, and critical observations. Nineteen species are included, one, *Bryopsis magellanica*, being new. E. S. G.

Contribution to the Study of the Verticillate Siphoneæ of the Limestone of Villanova-Mondovi.—AMALIA BARETTI (*Att. Soc. Ital. Sci. Nat. e Mus. Civ. St. Nat. Milano*, 1919, **58**, 216–36, figs. in text). A determination of the verticillate Siphoneæ from the triassic limestone of Villanova according to Pia's classification. Ten species are recorded, representing three genera—*Diplopora*, *Kantia*, *Teutloporella*. *Kantia monregalense* and *K. Brunoi* are described as new species. E. S. G.

Researches on the Laminarias of the French Coasts.—C. SAUVAGEAU (*Mém. Acad. Sci. Paris*, 1918, **56**, 240, 85 figs. in text). An exhaustive account, with illustrations, of all the work on the subject carried out by the author. In an introduction, after a short summary of the work of other authors and their conclusions, the results hitherto unpublished of the author's cultures of *Chorda Filum* are briefly described. The embryospore germinates, and the resulting plantlet is entirely comparable with that described for *Laminaria*, the swollen distal cells representing a prothallus. After fifteen days two or three cells were observed, which, not being of uniform size, were presumably male and female. Then growth slackened off, the prothalli developed septa and branched, producing short filaments of torulose or irregular globular cells. Neither plantlets (with one exception) nor sexual organs were obtained. The author suggests that the prothallia of *C. Filum* at Roscoff, at least under certain conditions, may be apogamous, and that the plantlets arise direct at the expense of a cell of the prothallus. An examination of *Dictyosiphon fœniculaceus* produced more complete results. Alternation of generations takes place, but of a quite different character from that of *Laminaria*. The zoospores produce a prothallus bearing plurilocular organs, the motile elements of which are isogamous gametes; the zygotes, or the parthenogenetic gametes, give rise to a protonema on which appear the plantlets of *Dictyosiphon*. The alga known under this name is merely the sporophyte of the entire individual. The two types respectively of *Laminaria* and *Dictyosiphon* represent doubtless the mode of reproduction followed by a number of other Phæophyceæ; but a difficulty still remains in explaining the seasonal existence of certain epiphytes which appear suddenly and abundantly, grow rapidly, and disappear after fructification. The reproductive elements which they disseminate cannot be those which germinate the following season, especially when the host plant itself is ephemeral. An instance of this is *Litosiphon pusillus* on *Chorda Filum*. What is the intermediate stage of this and many similar species? Other points of interest in the introduction must be studied in the original work. The first part of the memoir is devoted to *Saccorhiza bulbosa*:—1. Geographical distribution. 2. Biology (*S. bulbosa* is an annual). 3. Development: sporangia and zoospores, male and female prothallia, etc. 4. Nature and origin of the tissues of the young plant. The remaining parts treat respectively of *Laminaria flexicaulis*, *L. Lejolisii*, *L. Cloustonii*, *L. saccharina*, and *Alaria esculenta*: two chapters, biology and development, being devoted to each. A bibliography and synopsis of contents complete this important memoir. E. S. G.

Dissemination and Naturalization of Certain Marine Algæ.—C. SAUVAGEAU (*Bull. Inst. Océanogr. Fondn. Prince de Monaco*, 1918, No. 342, 28 pp.). A discussion of the gradually enlarged distribution of certain well-known species, their means of transport, and the difficulties they encounter. The species discussed are *Cystoseira granulata*, *Alaria esculenta*, which are probably drift-weed, and *Colpomenia sinuosa*, *Laminaria Lejolisii* and *Bonnemaisonia hamifera*, which are chance emigrants and probably transported by some ship. The invasion of *Colpomenia sinuosa* is likened to that of *Elodea canadensis* in the mischief they both cause. Certain forms, *Himanthalia lorea*, *Cystoseira concatenata* and *Sargassum vulgare* appear unable to acclimatize themselves to the conditions in the Gulf of Gascony, though frequently brought there. E. S. G.

Notes on Algæ New to Japan.—KICHISABURO YENDO (*Bot. Mag. Tokyo*, 1918, **32**, 65–81, 175–87). Concluding chapters. The number of algæ treated in this series of papers amounts to 178 species, varieties and forms; and the author suspects that several more epiphytic and parasitic species have yet to be added to the list. In the final chapter he discusses questions of synonymy and distribution. It is interesting to find that 38 marine algæ are common to Japan and Europe; also that, by careful study of the living plants, 39 species of *Sargassum* have been reduced to 19. An index to the genera and species which are discussed in the scattered series of papers is provided. A. G.

Fungi.

Blepharospora terrestris (Sherb.) Peyr. — B. PEYRONEL (*Atti Real. Accad. dei Lincei*, 1920, ser. 5, **29**, 194–7). The fungus here described was found to be causing serious damage to plants of *Lupinus albus*. The author found that the roots of the plants were specially affected, and in the cells he found the characteristic phycomycetous hyphæ and a few oospores. He was also able to observe the formation of zoospores and later their germination. The fungus was placed in *Phytophthora* by Sherbakoff, but, according to Peyronel, its place is in the above genus. A. LORRAIN SMITH.

Large Pyrenomycetes. II.—C. G. LLOYD (*Cincinnati, Ohio*, 1919, 17–32, 23 figs.). Lloyd gives a synoptic key to seventeen genera of this group. He selects a few of these for special note: *Kretzschmaria*, a tropical genus, with stems bearing heads that become confluent; *Daldinia*, of which only one species, *D. concentrica*, is common. A new genus, *Carnostroma*, has been established by Lloyd; the species *C. thyrsus* has a stem 6–8 in. long with a conical fleshy stroma at the apex; *Penzigia*, *Sarcoxylon* and *Glaziella*, all rare genera, are figured and discussed. A. L. S.

Life-History of Ascobolus magnificus.—B. O. DODGE (*Mycologia*, 1920, **12**, 115–34, 2 pls., 28 figs.). This fungus, originally from Porto Rico, has been kept in culture by the author for several years. He

discusses (1) the development of the primordia—ascogonia and antheridia, (2) the asexual or *Papulospora* stage, (3) intrahyphal mycelium, and (4) the necessity of two strains in sexual reproduction. He finds that both ascogonia and antheridia are erect structures (air being evidently necessary at the origin of the ascocarps), and that the ends of the two bodies fuse. The ascogenous cell then begins to enlarge and to produce ascogenous hyphæ. A description of the bulbils or *Papulospora* stage follows, and the appearance of hyphæ within older hyphæ of the same species. In spore cultures of one strain there is no fertilization, only ascogonia or antheridia arise ; but sexual reproduction occurs in cultures containing two strains properly chosen. Difficulty was experienced in obtaining the germination of any of the spores. A. L. S.

Another New Truffle.—W. A. MURRILL (*Mycologia*, 1920, **12**, 157–8, 1 fig.). The new species, *Tuber Shearii* Hark., was collected and described by Harkness before his death in 1899. It differs from allied species in the markings on the large spores. A. L. S.

Mycotorula turbidans Will.—H. WILL and F. O. LANDTBLOM (*Zeitschr. Ges. Brauw.*, 1919, **42**, 367–70 ; see also *Journ. Inst. Brew.*, 1920, **26**, 261–2). The new *Torula* produces turbidity in beer. Such *Torulæ* were rare before the war, but the writers suggest that the wort being weak allows the development of alien organisms. The one described appears to thrive well in competition with the normal beer yeast. As the beer matures the cloudiness disappears, as the flocks, at a certain stage of development, fall to the bottom of the storage vessel. *Mycotorula* is described, and the results obtained in cultures, etc., are given. A. L. S.

Glœosporium Tremulæ and Glœosporium Populi-albæ.—A. VAN LUYK (*Ann. Mycol.*, 1919, **17**, 110–3, 1 fig.). The author considers that the two species are identical. He finds a curious attachment between the spores whereby chains are formed by lateral bridges. Similar bridging connexions are the characteristic feature of *Titæospora* Bubák, but as the spores in the above plants are simple a new genus is formed, *Titæosporina*. A. L. S.

Uredineæ with Swelling Spore-membranes.—H. and P. SYDOW (*Ann. Mycol.*, 1919; **17**, 101–7). The authors have discussed some unusual forms. Two species from Paraguay and from Ceylon classified as *Uredo* forms have now been determined as teleutospore stages. They are distinguished by the swollen walls of the spores covered with projections ; the spores are one-celled and of rather large size. The authors place them in a new genus, *Ctenoderma*. A discussion follows on the method of distinguishing *Uromyces* and *Puccinia*. In both these genera are found forms with swollen walls and with a large number of germinating pores. Sydow proposes two genera to include these—*Dichlamys* for those belonging to *Puccinia*, and *Haplopyxis* for the *Uromyces* forms. Still another genus is established, *Trochodium*, in which the teleutospores are one-celled, with swollen furrowed walls and with one germ pore. A. L. S.

Puccinia Malvacearum and the Mycoplasm Theory.—M. A. Bailey (*Ann. Bot.*, 1920, **34**, 173–200). The writer's aim was to test Eriksson's repeated statement that rust persisted in plants as a mycoplasm in the seed. He grew different series of hollyhocks from seed—a certain number of plants in the open, others in enclosed globes protected from infection. All the plants in the open became infested with hollyhock rust; those in the globes were free from disease until finally they were sprayed with rust spores. An account of these experiments is given and the results tabulated as regards the various plants. All disease was proved to arise from external infection and in no case to come spontaneously from a mycoplasm in the cells. A. L. S.

Heteroccism and Specialization in Puccinia Caricis.—Jakob Eriksson (*Rev. Gén. Bot.*, 1920, **32**, 15–8). By a series of inoculation experiments Eriksson has proved that *Puccinia Caricis* is a collective species and includes a number of biologic forms, and several different forms may be found on the same species of *Carex* and the same species of *Ribes*, the alternate host. A. L. S.

Facultative Heteroccism in Peridermium cerebrum and Peridermium Harknessii.—E. P. Meinecke (*Phytopathology*, 1920, **10**, 279–97). Meinecke distinguishes sharply between the two *Peridermium* species. The last-mentioned is now confined to the gall forms on mountain pines, and produces uredinia and teleutospores on Scrophulariaceæ. *Peridermium cerebrum* forms galls on pines of the Pacific coast; the alternate hosts are *Quercus* spp. A. L. S.

Puccinia graminis on Berberis canadensis.—E. C. Stakman and L. J. Krakova (*Phytopathology*, 1920, **10**, 305–6). A research was undertaken to determine if *Berberis canadensis* would prove to be an alternate host to *Puccinia graminis*. The workers found that the *Berberis* in question was badly rusted and that the rust spread to wheat. They recommend the eradication of the bushes which are especially abundant on limestone formations. A. L. S.

Æcidial Form of Uromyces Genistæ-tinctoriæ.—P. Dietel (*Ann. Mycol.*, 1919, **17**, 108–9). The æcidial form of this rust develops on *Euphorbiæ*. The author proved this by inoculation experiments; he describes the type of deformation on the *Euphorbia* plants caused by the fungus. A. L. S.

New or Noteworthy North American Ustilaginales. — H. S. Jackson (*Mycologia*, 1920, **12**, 149–56). The writer reports for the first time in North America the bunt of rye, *Tilletia Secalis*; it had been collected in 1892 by L. M. Underwood at Syracuse, New York. A new species, *Urocystis Trillii*, on *Trillium chloropetalum* forms conspicuous sori on the leaves. Another new to America is *Sorosporium Junci*, two collections of which were made on *Juncus bufonius* in Oregon. A. L. S.

Biology of Fomes applanatus.—J. H. White (*Trans. Roy. Canad. Inst.*, 1920, **12**, 133–74, 2 figs., 6 pls.). *Fomes applanatus* has been

proved to be a wound parasite; it is very common and very destructive; it attacks practically all deciduous trees as well as conifers, both living and dead. From the mature fungus there is an enormous spore discharge, but the spores do not retain viability for more than six and a half months. Cultures were made on wood, and the effect produced by the growth of the fungus was carefully noted. Wood rotted by this *Fomes* shows a mottled appearance; this is due to the destruction of the tissues at certain points and the formation of pockets filled with mycelium. In the later stages of decay the fungus was accompanied by bacteria and other fungi. On living trees the fungus was observed to have travelled upward in the heart wood and outward through the sapwood. It is often quickly destructive. A. L. S.

Polyporaceæ of Bengal. Part III.—S. R. Bose (*Bull. Carm. Med. Coll. Belgachia*, 1920, **1**, 1–5, 7 pls.). The author records twelve different species of *Poria*, *Trametes*, *Fomes*, etc. He gives full descriptions, habitat, etc. All of those listed grew on dead wood. A. L. S.

Mycological Notes for 1919.—L. O. Overholts (*Mycologia*, 1920, **12**, 135–42, 2 pls.). The author comments on the abundant growth of fungi in central Pennsylvania during 1919. Many species have been added to recorded lists, some of them of rare occurrence. It is on some of these that the notes are based:—*Clavaria ornatipes*, with brown hairs on the stem; *Merulius aureus*, a rare species on pine; *Mucronella Ulmi*, a rare species of a rare genus with short awl-shaped teeth; *Tremellodon gelatinosum* and others. A. L. S.

Mycological Notes. I.—F. Petrak (*Ann. Mycol.*, 1919, **17**. 59–100). The author discusses a number of fungi (microscopic) already known, both of Fungi Imperfecti and of Pyrenomycetes. He has also established for both groups several new genera:—*Keissleriana* (near to *Dothiora*), *Cytoplacosphæria*, *Pseudopleospora*, *Neokeissleria*, *Chætocytostroma*, *Blennoriopsis*. *Macrodiaporthe*, and *Phæodiaporthe*. Most of the genera are Pyrenomycetes. *Chætocytostroma* and *Blennoriopsis* belong to Fungi Imperfecti. A. L. S.

Mycological Notes.—C. G. Lloyd (*Cincinnati, Ohio*, 1919, N. 60, 862–76, 34 figs.). The present notes are mainly concerned with the genus *Pterula*, rare in this country and in North America, but more common in the tropics. Lloyd figures and describes all the known species. He then discusses a number of tremellaceous plants, *Tremella*, *Auricularia*, *Exidia*, etc. A. L. S.

Index of the Mycological Writings of C. G. Lloyd.—(*Cincinnati, Ohio*, 1916–9, **5**, 1–24, 1 pl.). A subject index of the papers contributed by Lloyd to mycological literature. A portrait of the author is published. A. L. S.

Mycological Fragments.—Franz v. Höhnel (*Ann. Mycol.*, 1919, **17**, 114–33). The author publishes criticisms on a number of established species. He records the finding of *Tricholoma tenuiceps* Cke. & Mass. in Vienna woods, the first time it has been found out of England so far

as known. *Melanopsamella*, a new genus of *Melanommeæ*, is founded on *Eriosphæria inæqualis* Grove; the conidial form is *Gonytrichum*. He finds that the genus *Echusias* is synonymous with *Fracchiæa*. Several new species are described. A. L. S.

Amount of Copper required for the Control of Phytophthora infestans.—O. BUTLER (*Phytopathology*, 1920, **16**, 298–304). The author records results arrived at from spraying experiments carried out in 1919, a season very favourable to the spread of the disease. The amount of copper necessary per acre per annum lies between twenty-four and twenty-six pounds. A. L. S.

The Skin Spot Disease of Potato Tubers.—(*Journ. Agric.*, 1920, **26**. 1245–50, 1 pl.). The paper is an abridged and modified version of a report of work done by Miss M. N. Owen on the disease, and published in the *Kew Bull.*, N. 8, 1919. It is a disease that develops in storage, but it is not yet known whether infection takes place in the soil or during storage. The fungus, at first considered to be *Spicaria Solani*, has now been referred to *Oospora pustulans* sp. n.; it is confined to the surface layers of the potato, but may be so disfiguring that the commercial value of the tubers is very much lowered, and "eyes" may be prevented from forming. The writer advises the avoidance of spotted potatoes for planting. A. L. S.

Clover Stem-rot.—A. D. COTTON (*Journ. Agric.*, 1920, **26**, 1241–4, 1 pl.). This disease is due to *Sclerotinia trifoliorum*. It usually makes its appearance in November, and spreads as a sparse white mould over the foliage. In bad cases the fungus invades the roots and kills the plants outright. The sclerotia in the soil may retain their vitality for years. An interval of eight or twelve years should be allowed before re-sowing with clover. A. L. S.

Diseases of the Rhododendron.—HENRY SCHMITZ (*Phytopathology*, 1920, **10**, 273–8, 1 pl.). Descriptions of some of the more important diseases of rhododendron, both wild and cultivated, on the Pacific coast. The writer made cultures and inoculations of various parasites: *Sporocybe Azaleæ*, a bud rot; *Melampsoropsis piperiana*, a rust on a native rhododendron; and various other leaf parasites. He investigated also the witches-brooms of the native plant, but could not determine the causal agent. A. L. S.

Rot of Date Fruit.—J. G. BROWN (*Bot. Gaz.*, 1920, **69**, 521–9, 5 figs.). This disease was worked out by the author in Arizona. Dates had been brought to him very badly affected. On examining the trees many dates were found to be rotted, others were dry and mummified. Careful cultures showed that the fruit was first attacked by *Alternaria*, which induced mummification, but if the first attack were followed by *Aspergillus* and *Penicillium* on the diseased areas, the dates were quickly destroyed. A. L. S.

Entyloma Ranunculi injurious to Helleborus niger.—G. ARNAUD (*Bull. Soc. Path. vég. France*, 1919, **6**, 10–12; see also *Bull. Agric. Intell. Pl. Dis. Rome*, 1919, **10**, 747–8). The fungus attacks the

petioles near the base, and the leaf dies off. On the diseased petioles there develops also *Coniothyrium Hellebori*, followed by other fungi and bacteria which complete the work of destruction. A. L. S.

Lichens.

Lichen Flora and Lichen Vegetation of Iceland.—Olaf Galløe (*The Botany of Iceland*, 1919–20, **2**, 1, 1–248). In the introduction the author gives an account of work done by previous collectors. This is followed by a critical examination of the methods of classification and by the lists of lichens, most of them seen and collected by himself. In these lists he notifies the occurrence of the lichens in Greenland and in Great Britain. Galløe discusses the means of dispersal and distribution, with special reference to the conditions that prevail in Iceland; he concludes that wind is there the chief agent in scattering spores or portions of the lichen thallus. The special ecology of Iceland lichens occupies a good deal of his paper. There are few trees, and the bark lichens are mainly those growing on old birch trunks. Rock and soil lichens are numerous, but Galløe decides that abundant growth is inhibited by the extreme cold of such a northern region.

A. Lorrain Smith.

Hints for Lichen Studies.—Albert C. Herre (*Bryologist*, 1920, **23**, 26–7). Herre deplores the small number of people that interest themselves in the study of lichens, seeing the plants are more or less abundant everywhere. He concludes that it is the lack of manuals that has hindered students. He suggests as an interesting field of study the observation of yearly growth in definite species and individuals. He also adds observations on the meaning of the lichen plant, which is largely a physiological species, but shows constant heredity. A. L. S.

Mycetozoa.

Critical Study of the Slime-Moulds of Ontario.—Mary E. Currie (*Trans. Roy. Canad. Inst.*, 1920, **12**, 247–308, 3 pls.). The majority of the mycetozoa recorded in this paper were collected in the Lake Ontario region; a few were from other parts of Ontario. The writer enumerates 29 genera and 117 species and varieties. Of these 3 species and 2 varieties are new to North America. Interesting biological and descriptive notes are given, along with the exact localities and substrata.

A. Lorrain Smith.

Mycetozoa and Disease.—J. Jackson Clarke (*Protozoa and Disease*, 1920, **5**, 1–133, 1 pl., 46 figs; London: Ballière, Tindall and Cox). The author claims to have proved the occurrence of mycetozoa in cancer. He gives a history of mycetozoa, more especially of their development as observed in cultures, and adds his own observations, which are mainly concerned with the culture of *Didymium difforme*. He then describes cultures of very similar organisms that developed from cancer. Careful figures of the organisms in both cases are placed side by side. He gives arguments and reasons in support of his facts. He contrasts, for instance, in a striking figure the formation of capillitium fibres in tubers and those in a mycetozoon (*Comatricha nigra*), both examples taken from his own cultures. A. L. S.

METALLOGRAPHY.

Some Theoretical Principles of Alloying.—ROBERT J. ANDERSON (*Chemical and Metallurgical Engineering*, August 25, 1920, **23**, No. 8). A discussion of possible applications of such general concepts as may be drawn from the equilibrium diagram, heat of alloy formation, thermit reaction, diffusion and solution to problems connected with the production of aluminium-copper alloys in the foundry.

Studies of the Macrostructure of Cast Steel.—FRED. G. ALLISON and MARTIN M. ROCK (*Chemical and Metallurgical Engineering*, Sept. 1, 1920, **23**, No. 9). Simple and reliable procedure is outlined for the development and record of macrostructure. A peculiar banded structure is described. Symmetrical arrangement of dendrites is necessary for consistent physical tests. Pouring cold metal suppresses dendrites.

Some Commercial Heat-treatments for Alloy Steels for Structural Purposes.—A. H. MILLER (*Chemical and Metallurgical Engineering*, July 21, 1920, **23**, No. 3). A general discussion of principles of heat-treatment, having especial reference to a nickel-chromium steel, the effect of time in complex heat-treatments, and the development of simple heat-treatments from the complex.

The Crystalline Structure of Antimony.—R. W. JAMES and N. TUNSTALL (*Phil. Mag.*, August, 1920). This research follows the lines laid down by Professors W. H. and W. L. Bragg. It is remarkably interesting in view of the structure of antimony and its alloys as usually seen microscopically. F. I. G. R.

On the Electrical Conductivity of Copper Fused with Mica.—A. L. WILLIAMS and OTHERS (*Phil. Mag.*, Sept., 1920). It is found that samples of copper fused with mica exhibit a very large fall in resistance when gradually subjected to rising temperatures. Photomicrographs of specimens at different magnifications are given. The illumination in some cases was oblique, in others direct. Ammonia was employed as the etching re-agent. F. I. G. R.

The Economic Selection of Coal.—A. L. BOOTH (Iron and Steel Institute Meeting, Sept., 1920). Although dealing chiefly with coal from the industrial standpoint, the author gives much information of interest to microscopists, including a number of coloured plates prepared from photomicrographs. F. I. G. R.

Temper-brittleness of Nickel-Chromium Steels.—R. H. GREAVES and J. J. A. JONES (Ironand Steel Institute Meeting, Sept., 1920). The paper deals with (1) the range in which temper-brittleness is produced ; (2) the rate at which temper-brittleness is produced ; (3) the susceptibility of certain steels to develop temper-brittleness ; (4) the effect of the change from the brittle to the tough condition on a few of the physical properties of the steel. F. I. G. R.

The Constitution of the Nickel-Iron Alloys.—D. Hanson and H. E. Hanson (Iron and Steel Institute Meeting, Sept., 1920). The purpose of the investigation is: (1) the determination of the effect of small quantities of nickel on the critical points of pure iron; (2) an examination of Osmond's theory of the nickel-iron alloys, and the determination, if possible, of the "stable" diagram of the nickel-iron alloys.

F. I. G. R.

On Graphitization of Iron-Carbon Alloys.—K. Honda and T. Murakami (Iron and Steel Institute Meeting, Sept., 1920). The authors determine the period of graphite formation in iron-carbon alloys during cooling, and the condition of its occurrence. F. I. G. R.

On the Formation of Spheroidal Cementite.—K. Honda and S. Saitô (Iron and Steel Institute Meeting, Sept., 1920.) The conclusions reached are:—1. If a quenched specimen be heated to below AcI, sorbitic cementite spheroidizes. 2. If a hyper-eutectoid steel be heated above AcI, but below the solubility line, and quenched, the spheroidization of the super-eutectoid takes place. 3. If a lamellar pearlitic steel be heated to just AcI, or a little above, for a certain interval of time, spheroidization takes place. 4. Granular pearlite spheroidizes by being heated below AcI for a sufficiently long time. 5. If AcI be not reached, the spheroidization of lamellar cementite can never proceed. If the maximum temperature exceed a certain limit above AcI and the steel be then cooled, cementite appears as a lamellar pearlite. 6. The temperature interval of spheroidization in low-carbon steels is very small, extending to only about 20° C; it increases rapidly with the content of carbon. In very high carbon steels the interval amounts to about 100° C. F. I. G. R.

Indian Iron Making at Mirjati Chota, Nagpur.—A. McWilliam (Iron and Steel Institute Meeting, Sept., 1920). Under the microscope, sections of the iron showed mainly normal wrought-iron structure, but with bands of varying and much higher carbon content. Several sections were examined microscopically, and the carbon content was seen to vary from nearly nil to the eutectoid point. F. I. G. R.

Intercrystalline Fracture in Mild Steel.—W. Rosenhain and D. Hanson (Iron and Steel Institute Meeting, Sept., 1920).

Experiments on the De-oxidization of Steel with Hydrogen.—J. H. Whiteley (Iron and Steel Institute Meeting, Sept., 1920).

On Spherical Shell Crystals in Alloys.—J. E. Stead (Institute of Metals, Autumn Meeting, Sheffield, 1919). This is the first instalment of the author's work on this subject. Some truly beautiful photographs of structures in the alloys of tin, antimony, and arsenic are given.

F. I. G. R.

Distinguishing Lead in Brass and Bronze.—F. P. Galligan and J. J. Curran (*Metal Industry*, June 25, 1920, **16**, No. 26). A criticism on the method of distinguishing lead in brass and bronze by the application of sulphide etching, pointing out that as a means of detection it has no advantages, that lead is best detected in a polished and unetched specimen.

GEOLOGY.

On the Quartzite Pebbles of the Oldhaven (Blackheath) Beds of the Southern Part of the London Basin.—H. A. Baker (*Geological Mag.*, Feb. 1920).—1. The sarsen stones and pudding stones considered are cemented portions of sandy and pebbly lower Eocene strata. 2. The Woolwich and Reading beds have afforded one source of supply of these stones. 3. The pebbles of quartzite and siliceous flint conglomerate occurring in the Oldhaven (Blackheath) beds are rolled fragments of sarsen and pudding stone derived from the Woolwich and Reading beds. Photomicrographic illustrations are included in the memoir.

F. I. G. R.

On the Petrography of the Millstone Grit Series of Yorkshire.—A. Gilligan (Geological Society, May 21, 1919). Since Sorby's work on this subject, published in 1859, little has been done. The present author has undertaken much microscopical work on the Millstone Grit, and brings forward theories of great interest. F. I. G. R.

Notes on the Extraneous Minerals in the Coral Limestones of Barbados. — J. B. Harrison and C. B. W. Anderson (Geological Society, June 4, 1919). Characteristic representative specimens of the fossil-reef corals, etc., were examined microscopically. A note on the proportions of titanium oxide in the Barbados Oceanic Clays and in some of the "Challenger" and "Buccaneer" deep-sea dredgings is appended. F. I. G. R.

On the Silurian Rocks of May Hill.—C. I. Gardiner (Geological Society, May 21, 1919). In the same paper, Dr. F. R. C. Reed describes a new species of *Lichas* from the Wenlock Limestone, and a new variety of *Calymene papillata*. F. I. G. R.

On the Dentition of the Pelalodont Shark "Climaxodus."—A. Smith Woodward (Geological Society, June 4, 1919).

On Syniogothyris Winchell, and Certain Carboniferous Brachiopoda referred to Spiriferina d'Orbigny.— F. J. North (Geological Society, Jan. 7, 1920).

Some Microchemical Methods.—A. Brammall (*Geological Mag.*, March, 1920). The tests afforded by ferricyanide, ferrocyanide, and thiocyanate solutions may be adapted to the microchemical investigation of certain rocks in thin section. F. I. G. R.

NOTICES OF NEW BOOKS.

Modern Study of Heredity. By T. H. MORGAN. (*The Physical Basis of Heredity*, Philadelphia and London, 1919, 1–305, 117 figs.)

The two fundamental principles of heredity discovered by Mendel were the law of segregation and the law of independent assortment of the genes. Sutton, in 1902, was the first to point out clearly how the chromosomal mechanism, then known, supplied the necessary mechanism to account for Mendel's two laws. The acceptance of this mechanism at once leads to the logical conclusion that Mendel's discovery of segregation applies not only to hybrids, but also to normal processes that are taking place at all times in all animals and plants, whether hybrids or not. Since 1900 four other principles have been added. These are known as linkage, the linear order of the genes, interference, and the limitation of the linkage groups.

Mendelism rests on the theory of a clean separation of the members of each pair of factors (genes). In every heterozygote the factor for the dominant and that for the recessive are supposed to come into relation to each other and then to separate at the ripening of the germ-cells. The point is the clean separation of the genes without contamination (unless as an exceptional phenomenon). Mendelian characters are not confined to the surface. A common class of characters showing perfect Mendelian behaviour are so-called lethals that destroy the individual when in homozygous condition. In recent years an entirely unexpected and important discovery in regard to segregating pairs of genes (allelomorphs) has been made. In an ever-increasing number of cases it has been found that there may be more than two distinct characters that act as allelomorphs to each other. For example, in mice, yellow, sable, black, white-bellied grey, and grey-bellied grey (wild type) are allelomorphs—i.e. any two may be present (as a pair) in an individual, but never more than two. In all probability, apart from hybrids altogether, the germ-plasm is at first made up of pairs of elements, but at the ripening of the germ-cells these elements (genes) separate, one member of each pair going to one daughter-cell, the other member to the other cell.

The sperm and the egg pass through essentially the same stages during maturation, the essential feature of which is the conjugation of homologous (paternal and maternal) chromosomes followed by their subsequent segregation. Each egg and each sperm is left with half the original number of chromosomes—one of each kind, i.e. only a paternal or a maternal member of each chromosome pair. It is obvious that if one member of any pair contains material that produces an effect on some character as one of the end results of its activity, and the other member of the pair contains a different material, the behaviour of the

chromosomes at the time of maturation supplies exactly the mechanism that Mendel's law of segregation calls for.

Mendel's second law is the independent assortment of the genes. If at the maturation (whether of egg or sperm) the genes "tall" and "colour" go to one cell, then the genes "short" and "white" go to the other, or "short" and "colour" go to one cell, "tall" and "white" to the other. Four classes of germ-cells will be expected in the F_1 generation—viz. tall colour, tall white, short colour, and short white. Each pair of chromosomes, just before the reduction division, consists of a maternal and a paternal member; the evidence points to random or free assortment of some maternal chromosomes to one pole and some to the other, and similarly for the paternal chromosomes. This will account for the independent assortment of genes which Mendel's second law postulates.

But further investigation is disclosing an increasing number of cases in which free assortment does *not* occur. Many characters have been found to keep together in successive generations instead of assorting freely. This is called linkage, and it may be complete or occasional. The correlative aspect of linkage is crossing over, and inasmuch as it involves a change in the mechanism that gives linkage, it is entitled to rank as one of the fundamental principles of heredity. It means that there is an interchange of blocks of genes between homologous pairs of chromosomes. Pairs of characters may be spoken of as loosely linked, meaning that crossing over of genes frequently takes place, or as strongly linked, meaning that crossing over is very infrequent. It is probable that there is a limiting value for crossing over, and if this can be established it may lead to the discovery of the lower limit of size of the gene (in terms of chromosome length). The crossing over, which may occur in germ-cells of the male and not in those of the female, is not effected earlier than the time of the conjugation of chromosomes, but it can be effected at the time when the conjugation is known to occur. In regard to all this, however, there is still considerable uncertainty.

The data in regard to the linkage of characters and the correlative phenomenon of crossing over lead to the conclusion that the genes are arranged in linear order, standing at definite levels in the chromosomes and definitely spaced. Ingenious arguments lead to the conclusion that the size of the blocks that interchange in a crossing over depends on the location of the breaking point, and that a break in one region interferes with a break in another region. A correspondence between the number of linkage groups and the number of chromosome pairs has been proved in *Drosophila melanogaster*, and no case is known where the number of linkage groups exceeds the number of chromosome pairs. It may be that a limitation of the linkage groups to the number of chromosomes pairs is a fundamental principle of heredity. An interesting fact is the variability of the amount of crossing over in certain cases; the amount differs at different temperatures in *Drosophila*, and it has also been shown that there are genes carried by the chromosomes themselves that affect the amount of crossing over.

One species may have twice as many chromosomes as a closely related one. So frequent is this that it can hardly be due to chance.

The implication is that the number of the original chromosomes has either become doubled or halved. If the number is simply doubled, there would be at first four of each kind of chromosome from the point of view of genetic contents. There is some direct evidence that this tetraploidy may occur. There may be also doubling in one pair of chromosomes, and there are other modes of variation in the number of chromosomes.

The discovery that the female in certain species has two X-chromosomes, and the male only one X-chromosome, either with a Y-chromosome in addition (Stevens) or without the Y (Wilson), established a view first suggested by McClung that the difference between the sexes is connected with the distribution of particular chromosomes. It may be that the presence of two chromosomes (XX), in connection with the rest of the cell complex, causes a female to develop; while only one sex chromosome (X), in connection with the rest of the cell, causes a male to develop. Or it may be that XX and X are merely indices of sex—i.e. that the sex-chromosomes follow sex and do not determine sex. According to Morgan, the evidence is now conclusive that sex follows the chromosomes. He also shows how the chromosome theory of sex may apply to "intersexes," gynandromorphs, and allied phenomena.

In so far as parthenogenetic reproduction takes place without reduction in the number of the chromosomes, the expectation of any character is that it will have the same frequency distribution in successive generations, because the chromosome group is identical in each generation. The same will apply to a species propagating vegetatively, or to cases of sexual reproduction in a homozygous group of individuals (as in Johannsen's pure lines).

Almost the whole interpretation outlined above rests on the postulate that the chromosomes are the bearers of the hereditary factors or genes. There is cytological and embryological evidence supporting this view, but it is the genetic evidence that is convincing. That there may be substances in the cytoplasm that propagate themselves there and that are outside the influence of the nucleus must be conceded as possible; but, aside from certain plastids, all the Mendelian evidence fails to show that there are such characters. It is difficult to determine whether a peculiarity of the ovum-cytoplasm, such as colour, is due to inherited plastids or to the influence of the ovum-nucleus before fertilization.

A gene is to be thought of as a certain amount of material in the chromosome that may separate from the chromosome in which it lies, and be replaced by a corresponding part (and none other) of the homologous chromosome. It is of fundamental significance in this connexion to recognize that the genes of the pair do not jump out of one chromosome into the other, so to speak, but are changed by the thread breaking as a piece in front of or else behind them, but not in both places at once, as would be the case if only a single pair of allelomorphs were involved each time.

A number of general propositions may be stated:—1. A gene is associated with manifold effects. Whatever it is in the germ-plasm that produces white eyes produces other peculiarities as well. 2. The variability of a character is not necessarily due to variability in the gene;

much is due to variability in the environmental conditions of development. 3. Characters that are indistinguishable—e.g. whiteness in poultry may be produced by different genes. 4. Each character is the product of many genes, but each of these may change without the others changing. Both in segregation and in crossing over each pair is inseparable from the others.

Of mutations it may be said that they appear infrequently, that the change is definite from the beginning, that some at least are recurrent, and that the difference between the old character and the new one is small in some cases and greater in others. Their origin remains obscure. As to their supposed "chance" character, it is pointed out that the degree of development of any character increases the probability of further stages in the same direction. Species are to be thought of as groups of genes, and related species have a good many genes in common. Thus similar mutations are likely to occur in different species, and there is experimental evidence of this in *Drosophila*. J. A. T.

Traité de la Lumière. Par Christian Huyghens. 1920. 155 × x pp. Price 3 fr. 60. Published by Gauthier-Villars et Cie., Paris.

Microscopical Preparations. Catalogue of Zoological and Botanical Material, Fresh and Preserved. 1920. Flatters and Garnett, Ltd., 309 Oxford Road, Manchester.

Report of the Enquiry Committee on the Standardization of the Elements of Optical Instruments. 39 pp. Price 1*s*. net. Published for the Department of Scientific and Industrial Research by His Majesty's Stationery Office.

National Physical Laboratory Report for the Year 1919. 152 pp. Price 5*s*. net. Published by His Majesty's Stationery Office.

Common Diatoms. By Thomas K. Mellor, F.R.A.S. 1920. 16 pp., 7 pls. Price 6*s*. net. Published by William Wesley and Son, 28 Essex Street, Strand, W.C.

Studies on Acari. No. 1. The Genus Demodex Owen. By Stanley Hirst. 1919. 44 pp., 13 pls. Price 10*s*. Published by the British Museum (Natural History), Cromwell Road, S.W.7

Marine Boring Animals. By W. T. Calman, D.Sc. 1919. 36 pp. Price 1*s*. Published by the British Museum (Natural History), Cromwell Road, S.W.7

The British Charophyta. By James Groves, F.L.S., and George Russell Bullock-Webster, M.A., F.D.S. 1920. 142 pp., 20 pls. Published by the Ray Society.

A Monograph of the British Orthoptera. By William John Lucas, B.A. 1920. 264 pp., 25 pls. Published by the Ray Society.

PROCEEDINGS OF THE SOCIETY

AN ORDINARY MEETING

OF THE SOCIETY WAS HELD AT NO. 20 HANOVER SQUARE, W., ON WEDNESDAY, JUNE 16TH, 1920, PROFESSOR JOHN EYRE, PRESIDENT, IN THE CHAIR.

The Minutes of the preceding Meeting were read, confirmed, and signed by the President.

The nomination papers were read of two Candidates for Fellowship.

New Fellows.—The following were elected Ordinary Fellows of the Society :—

Mrs. Bertha Altof.
Mr. Herbert Graham Cannon, B.A., F.Z.S.
Mr. William Edmund Cooke, M.D., F.R.C.P., D.Ph.

A Donation was reported from Dr. E. Penard, of Geneva, an Honorary Fellow of the Society, consisting of 100 slides covering nearly all the genera of Fresh-water Rhizopoda and a few Ciliata.

Mr. Scourfield exhibited a number of Dr. Penard's preparations, including the following :—*Difflugia hydrostatica*, showing test formed of frustules of the plankton Diatom *Cyclotella* ; *Cucurbitalla mespiliformis*, with symbiotic zoochlorellæ ; *Spirochona gemmipara*, and *Arcella dentata*.

A hearty vote of thanks was accorded to Dr. Penard.

Mr. W. G. Collins read a paper on "A Universal Microtome," written by Sir Horace Darwin, F.R.S., and himself. The paper was illustrated by lantern slides and exhibits, and is printed in this issue of the Journal (see page 283). Asked as to what would be the probable price of the instrument, Mr. Collins said that they hoped it would not exceed £20.

The President proposed a very hearty vote of thanks to the authors of the paper, and this was carried by acclamation.

Mr. Lancelot Hogben, M.A., B.Sc., read a paper on "The Problem of Synapsis." This paper is printed in this issue of the Journal (see page 269).

Dr. Gatenby thought that the problem of heredity was to be attacked from the nucleus. It was probably true that in specialized forms there might be a partial handing on of the hereditary functions of the nucleus to certain inclusions of the cytoplasm, but he thought in the long run it could be shown that the functions had been handed on by the nucleus which was at the bottom of everything.

The President proposed a very hearty vote of thanks to Mr. Hogben, which was carried by acclamation.

A vote of thanks was accorded to Messrs. Hawksley and Sons for the loan of microscopes.

The business proceedings then terminated.

REPORT ON THE COLLECTION OF METALLURGICAL SPECIMENS RECENTLY PRESENTED TO THE SOCIETY BY SIR ROBERT HADFIELD, Bart., F.R.S.

By F. Ian G. Rawlins.

(*Read November* 19, 1919.)

The primary purpose of this communication is to bring to the notice of Fellows a collection of Metallurgical Micro-specimens which Sir Robert Hadfield has been good enough to give to the Society. The report will deal with the matter in the following order:—1. Early Suggestions. 2. The Collection Itself. 3. Description of the more important Micro-Structures. 4. Preservation and Future Arrangements.

When these have been explained and discussed Fellows will be in a position to examine for themselves the selection of specimens from the collection which is on view this evening.

Before proceeding further I ought perhaps to mention that in June last the Council honoured me by asking that I would undertake the duty of curator of this collection. I assented with pleasure, so far as the pressure of other work permitted, and this, I trust, explains my presence here in this capacity to-night.

1. *Early Suggestions.*—In the Autumn of last year, about the beginning of the Session, a suggestion was made that this Society might become a means of furthering interest, and perhaps research, in metallography (i.e. the examination of prepared metal surfaces microscopically) if some specimens could be obtained to act as a nucleus of a collection which would be at the service of Fellows, in much the same way as the Society's general collection of slides. It is hardly necessary to point out that metal specimens cannot be purchased commercially, as is the case with some other kinds of objects, nor can they be prepared except by those who have the necessary appliances; and the number of persons so equipped is small. Taking account of these considerations, in December 1918 a letter was sent to Sir Robert Hadfield, pointing out our views upon the matter, and asking for his

assistance towards the much-needed collection of specimens. A reply was received from Sir Robert in which he generously promised to give a number of specimens from his Research Laboratory, adding at the same time an expression of his whole-hearted support of the scheme.

2. *The Collection Itself.*—After a short interval the gift of slides came to hand. It consisted of twenty specimens, including particularly interesting alloy steels, together with cast irons, and samples of varying carbon content after having received different thermal treatment, the whole thoroughly representative of modern metallurgical practice, and affording a wide range of interesting micro-structures. The specimens were ground down to level surfaces, but naturally the polishing and etching process had yet to be done. I may add that I was away at a considerable distance during this period, and consequently some delay was unavoidable before I was able to see the specimens and consider plans for their final treatment. After I had examined the specimens I approached Prof. H. C. H. Carpenter, Ph.D., F.R.S., asking whether he would be so kind as to allow the finishing process to proceed at the Royal School of Mines. To this he generously agreed, and to him we are indebted for his timely assistance and interest in the scheme. The sections were received back complete last July, since when they have been at the Society's Rooms.

3. *Description of the more important Micro-Structures.**—Sir Robert Hadfield enclosed a detailed list, giving the chemical composition and thermal treatment of each specimen, and in the light of this information it may be well for me briefly to review the most interesting points of the structures as seen under the microscope.

The "Armco" iron (2148) is a beautiful specimen. It consists, one might say wholly, of allotriomorphic crystals of "ferrite" (pure alpha iron). The outlines of the grains are developed on etching, due to minute differences of potential at their junctions. Neighbouring grains are coloured differently owing to variations in orientation. The "B.B." wrought iron (2112) shows the slag-inclusions very characteristic of such material. Comparison with a sample of mild steel (say 1350) shows the essential difference between these products. Wrought iron consists of a number of layers from between which the whole of the slag has not been squeezed out. The cast irons (912, 913) bring out the complexity of the constituents present, the white metal being especially interesting. The low, medium, saturated, and supersaturated carbon steels show the transition from a few isolated islets of "pearlite" (low carbon steel) through "saturated," where the whole structure is pearlitic, to "supersaturated," where areas of "cementite" (Fe_3C) make their appearance surrounding the "pearlite." The "special" steels "Era" and "Cr-Ni" are interesting, the former because they allow of the retention of "Austenite" (solid solution of carbon or Fe_3C in gamma iron), a constituent usually only stable at high temperature. The "Cr-Ni" specimens are pearlitic, as is generally the case.

4. *Preservation and Future Arrangements.*—It remains now to deal with this important matter. After careful consideration it was decided

* See also annotated list appended to this paper.

to purchase a desiccator in which the specimens may be kept free from rust and tarnish. The application of varnish to the faces is not to be recommended as a preservative. Either it must be dissolved off each time the sample is examined, or else applied as I described in a communication some time ago, which process is risky and not very satisfactory. I have had these sections under observation for some time, and I am hopeful that the method adopted will prove efficacious. Owing to the great delicacy of the surfaces, it will be understood that the greatest care is necessary in handling, as the infliction of a scratch means repolishing and etching.

With a view to making the collection generally useful, a vertical illuminator has been acquired for the Society. This, of course, is quite essential.

In the near future the question of a suitable light-source will need consideration. Personally I have obtained excellent results with a 200 c.p. ½-watt lamp. These lamps are very moderate in cost, and highly convenient. It is possible to use our existing lamps, though this is not easy. The vertical illuminator fixes successfully to one of the Society's stands, and it is not essential to use specially mounted objectives.

All things considered the Society may be congratulated upon its new possession. If it is appreciated, it will not be difficult, I expect, to obtain additions from time to time.

ANNOTATED LIST OF METALLURGICAL SPECIMENS PRESENTED TO THE ROYAL MICROSCOPICAL SOCIETY BY SIR ROBERT HADFIELD.

1. "Armco" Iron. — *R. No.** : 2148. *Analysis* : c.c.† 0.03 p.c., Mn 0·015 p.c. *Treatment* : As forged. *Mag.*‡ : × 100.

Polyhedral grains of "ferrite" (pure alpha iron). The individual grains are unequally coloured owing to difference of orientation of the crystalline elements composing them. The boundaries of the grains are developed on etching owing to minute differences of potential.

Ref.§ : "Metallography and Heat Treatment of Iron and Steel" (Sauveur) [hereinafter called "Metallography" (Sauveur)], p. 101, fig. 116 ; "Metallography" (Desch), p. 869, pl. xiii.A.

2. "B.B." Wrought Iron.—*R. No.* : 2112. *Analysis* : cc. 0·06 p.c., Mn 0·05 p.c. *Treatment* : As forged. *Mag.* : × 70.

Very typical structure of wrought iron. This is a longitudinal section consisting of "ferrite" and layers of slag, which latter are the

* *R. No.* = Reference Number.
† c.c. = combined carbon.
‡ *Mag.* = Suitable magnification.
§ *Ref.* = References to well-known treatises where descriptions of the structure (together with further details than here given) may be found. Where references to figures are given, these illustrate appropriately the particular structure in question.

cause of the so-called fibrous appearance of wrought iron. The ferrite is not really pure "ferrite," but a solid solution containing small percentages of silicon and other impurities.

Ref.: "Metallography" (Sauveur), chap. vi. with figs.; "Value of Science in the Smithy and Forge" (Cathcart), pp. 48, 49 and figs.

3. Grey Pig Iron.—*R. No.*: 912. *Analysis*: c.c. 0·52 p.c., graphite 3·5 p.c. *Treatment*: As cast. *Mag.*: × 100.

Matrix (white) of ferrite—darker parts pearlite—long black inclusions graphite. (The graphite has probably been removed in polishing. Only the cavities originally containing it remain.)

Ref.: "Metallography" (Sauveur), chap. xxii.; "Microscopical Analysis of Metals" (Stead) [hereinafter called "Micro-Analysis" (Stead)], figs. 119 and 120.

4. White Pig Iron.—*R. No.*: 913. *Analysis*: c.c. 3 p.c. *Treatment*: As cast. *Mag.*: × 150.

Light background cementite Fe_3C. Finely divided structure, pearlite. Laminated dark areas, sorbite.

Ref.: "Metallography" (Desch), p. 376, pl. xiv. A and B.

5. Low Carbon Steel.—*R. No.*: 1350. *Analysis*: c.c. 0·17 p.c., Mn 0·4 p.c. *Treatment*: Annealed. *Mag.*: × 100.

Polyhedral grains of ferrite; at the boundaries may be seen small areas of pearlite which under higher magnification show the typical laminated structure. Throughout the range of carbon steels up to 0·9 p.c. carbon, a gradual increase in the amount of pearlite present will be noticed.

Ref.: "Metallography" (Sauveur), chap. xv., fig. 234.

6. Low Carbon Steel.—*R. No.*: 428. *Analysis*: c.c. 0·17 p.c., Mn 0·4 p.c. *Treatment*: Quenched 900° C. water. *Mag.*: × 100.

The effect of heat treatment is here seen to consist in the breaking up of large areas of pearlite, and a close-grained homogeneous structure is obtained.

Ref.: "Metallography" (Sauveur), chap. xv., fig. 229.

7. Low Carbon Steel.—*R. No.*: 429. *Analysis*: c.c. 0·17 p.c., Mn 0·4 p.c. *Treatment*: Quenched 900° C. water, 400° C. air. *Mag.*: × 100.

This is a tempered specimen in which the treatment has been less drastic; consequently the structure is intermediate between Nos. 428 and 1350.

Ref.: "Metallography" (Sauveur), chap. xv. p. 239 *et seq.*

8. MEDIUM CARBON STEEL.—*R. No.* : 970. *Analysis* : c.c. 0·53 p.c., Mn 0·89 p.c. *Treatment*: Annealed. *Mag.* : × 100.

Deeply-etched specimen. The background is pearlite not well resolved. Surrounding it are membranes of ferrite.

Ref. : "Metallography" (Sauveur), p. 124, fig. 140.

9. MEDIUM CARBON STEEL.—*R. No.* : 977. *Analysis*: c.c. 0·53 p.c., Mn 0·89 p.c. *Treatment* : Quenched 820° C. and reheated to 600° C. *Mag.* : × 100.

This is a quenched and tempered specimen in which the structure, though resembling the foregoing, is more compact. This has been tempered at a higher temperature than usual, with the result that the effects of hardening have been greatly modified.

Ref. : "Metallography" (Sauveur), p. 239 *et seq.*

10. SATURATED CARBON STEEL.—*R. No.*: 2198. *Analysis*: c.c. 0·96 p.c., Mn. 0·36 p.c. *Treatment*: Annealed. *Mag.* : × 100.

This is practically entirely pearlite. Small indications of free cementite can be found here and there. At this carbon content (0·89 p.c. accurately) is the boundary between hypo-eutectoid steel (less than 0·89 p.c. C.) and hyper-eutectoid (more than 0·89 p.c. C.).

Ref. : "Metallography" (Sauveur), p. 127, fig. 146.

11. SATURATED CARBON STEEL.—*R. No.*: 2199. *Analysis*: c.c. 0·96 p.c., Mn 0·36 p.c. *Treatment* : Quenched 800° C. *Mag.* : × 100.

The treatment has resulted in the formation of martensite. A general idea of the structure can be obtained at this temperature, but higher magnification (some 300 diameters) is needed to resolve the martensite.

Ref. : "Metallography" (Desch), pp. 47 and 225.

12. SATURATED CARBON STEEL.—*R. No.*: 2200. *Analysis*: c.c. 0·96 p.c., Mn 0·36 p.c. *Treatment* : Quenched 800° C., tempered 400° C. *Mag.* : × 100.

The tempering treatment has relaxed the strain present in the quenched specimen. The theory of tempering is beyond the present purpose. A treatise on the subject will give imformation as to the tempering of steels of varying carbon content.

Ref. : "Metallography" (Sauveur), p. 242.

13. SUPERSATURATED CARBON SEEEL.—*R. No.*: 2195. *Analysis*: c.c. 1·41 p.c., Mn 0·38 p.c. *Treatment* : Annealed. *Mag.* : × 100.

Small membranes of cementite surround the pearlitic areas. The above magnification gives a good idea of the general structure. Higher magnification will resolve the aggregate, though the structure is fine-grained.

Ref. : "Value of Science in the Smithy and Forge" (Cathcart), p. 83, fig. 37.

14. SUPERSATURATED CARBON STEEL.—*R. No.*: 2196. *Analysis*: c.c. 1·41 p.c., Mn 0·38 p.c. *Treatment*: Quenched 800° C. *Mag.*: × 100.

Structure—very fine martensite, which, however, is just resolved at this magnification.

Ref.: "Metallography" (Sauveur), p. 245 *et seq.*

15. SUPERSATURATED CARBON STEEL.—*R. No.*: 2197. *Analysis*: c.c. 1·41 p.c., Mn 0·38 p.c. *Treatment*: Quenched 800° C., tempered 400° C. *Mag.*: × 100.

Membranes of cementite. The dark background is pearlite.

Ref.: As No. 2196.

16. HADFIELD'S "ERA" MANGANESE STEEL.—*R. No.*: 2035. *Analysis*: c.c. 1·2 p.c., Mn 11·98 p.c. *Treatment*: As cast. *Mag.*: × 150.

Structure of austenite here preserved at normal temperature by the presence of much manganese.

Ref.: "Metallography" (Sauveur), p. 343, figs. 320–325.
"Micro-Analysis" (Stead), p. 290.

17. HADFIELD'S "ERA" MANGANESE STEEL.—*R. No.*: 2030. *Analysis*: c.c. 1·2 p.c., Mn 11·98 p.c. *Treatment*: Quenched 1000° C. water. *Mag.*: × 150.

Polyhedral grains characteristic of "gamma iron." Samples possess, in general, low elastic limit, great hardness, wearing power and ductility.

Ref.: As No. 2035.

18. CHROMIUM NICKEL STEEL.—*R. No.*: 852. *Analysis*: c.c. 0·70 p.c., Cr 2·5 p.c., Ni 3 p.c. *Treatment*: Annealed. *Mag.*: × 600.

As usual with quaternary steels, the pearlite is very minute; in this particular, specimen is very characteristic.

Ref.: "Metallography" (Sauveur), p. 353.
"Metallography" (Desch), p. 66.

19 and 20. CHROMIUM NICKEL STEEL.—*R. Nos.*: 855 and 857. *Analysis*: c.c. 0·70 p.c., Cr 2·5 p.c., Ni 3 p.c. *Treatment*: (No. 855) Quenched 800° C. oil; (No. 857) Quenched 800° C. oil, 650° C. air. *Mag.*: × 600.

A minute structure, somewhat martensitic in 855 and sorbitic in 857. In industrial practice only steels low in carbon, nickel, and chromium are used. They combine the good points in nickel steels together with those of chrome steels; high elastic limit, ductility, and resilience.

Ref.: As No. 852.

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LONDON: PRINTED BY WILLIAM CLOWES AND SONS, LIMITED, GREAT WINDMILL STREET, W.1

THE MICROSCOPE

Its Design, Construction and Applications

A

SYMPOSIUM AND GENERAL DISCUSSION

HELD BY

THE FARADAY SOCIETY

THE ROYAL MICROSCOPICAL SOCIETY

THE OPTICAL SOCIETY

THE PHOTOMICROGRAPHIC SOCIETY

In co-operation with

THE TECHNICAL OPTICS COMMITTEE OF

THE BRITISH SCIENCE GUILD

WEDNESDAY, JANUARY 14th, 1920.

In the Rooms of the Royal Society, London.

[By kind permission of the President and Council.]

Including Reports of adjourned Discussions held in Sheffield, February 24th, and in London, April 21st, 1920.

EDITED BY F. S. SPIERS, B.Sc., F.INST.P.,
SECRETARY AND EDITOR TO THE FARADAY SOCIETY.

Truth discovering to Time, Science instructing her Children in the Improvements on the Microscope.

London, Published July 1st 1787, by Geo. Adams, No. 60 Fleet Street.

This Illustration is taken from the Book by George Adams.
"ESSAYS ON THE MICROSCOPE."
Printed in the year 1798.

JOURNAL OF THE ROYAL MICROSCOPICAL SOCIETY.
DECEMBER, 1920.

A SYMPOSIUM AND GENERAL DISCUSSION ON THE MICROSCOPE: Its Design, Construction, and Applications.

The Faraday Society, the Royal Microscopical Society, the Optical Society, and the Photomicrographic Society in co-operation with the Technical Optics Committee of the British Science Guild, meeting in joint session, held a Symposium and General Discussion on "The Microscope: Its Design, Construction and Applications," on Wednesday, January 14th, 1920, in the Rooms of the Royal Society at Burlington House, Piccadilly, London, by kind permission of the President and Council.

The purpose of the Symposium and Discussion, which was organised by a Joint Committee of the Co-operating Societies, at the initiative of Sir Robert Hadfield, Bart., was:—

(1) To stimulate the study of and research in microscopical science in the United Kingdom by indicating lines of progress in the mechanical and optical design of the instrument, showing by means of exhibits recent improvements in the

microscope and its technique and the varied uses to which the microscope can be applied as an instrument of research in the sciences, arts and industries.

(2) To encourage the manufacture in this country of the highest class of instrument and of the optical glass required for that purpose.

The meeting extended over two sessions: from 4.15 to 6.30 and from 8.15 to 10.30 p.m. The exhibition, which was probably the most important of its kind ever held in this country, took place during the afternoon preceding the meeting, in the Library of the Royal Society. The list of exhibits is printed as an Appendix to this Report.

The total attendance at the exhibition and meeting was not far short of one thousand, and the proceedings throughout were of an enthusiastic nature.

The meeting was presided over by **Sir Robert Hadfield, Bart., D.Sc., D.Met., F.R.S.**, President of *The Faraday Society*, supported by **Mr. J. E. Barnard**, President of the *Royal Microscopical Society*, **Professor F. J. Cheshire, C.B.E.**, President of the *Optical Society*, **Mr. F. Martin Duncan**, President of the *Photomicrographic Society*, and **Dr. R. Mullineux Walmsley**, Chairman of the *Technical Optics Committee of the British Science Guild.*

The Chairman, **Sir Robert Hadfield**, opened the proceedings with the following remarks:—

Whilst we must not congratulate ourselves too soon, we can at any rate say, by the large numbers present, by the extraordinary variety and number of valuable papers submitted, by the exhibits, both historical and modern, also by the interest shown generally, that this Symposium is going to aid in throwing more light on the important subjects with which it is attempting to deal.

I earnestly hope, as I am sure we all do, that as a result of our proceedings, not only will our knowledge—and knowledge is power—be increased, but that this country will be rendered independent of foreign supplies in products which it is so vital should be made at home. In this respect I should like to read a valuable letter I have received from that public-spirited and broad-minded citizen Lord Burnham, who is taking great interest in our deliberations and who had hoped to be present. In his letter he is kind enough to say:—

"It is, as you say, of vast importance to our future that we should do all we can to assist the British optical industry to meet foreign competition and to strike out new lines of advance for itself. We all know how far we were left behind in the days before the war and this time it is up to us to make good once for all.

I wish I could come myself, but I am deeply engaged on that day. It is a great thing that you and your colleagues should put yourselves at the head of such a movement."

I think we all feel stimulated by such encouraging words from a man like Lord Burnham, who, while not a scientist or technician, sees the great importance of this movement.

It is also a great satisfaction to find so many well-known representatives of science and technology taking part in our Symposium to-day. America has contributed several valuable communications, including those of Prof. Sauveur, who has done so much for the microscope and metallography, Dr. Zay Jeffries, who has made the subject of grain size peculiarly his own, and others.

We have important communications from France and Italy in the papers of Monsieur Eugene Schneider, Prof. H. le Chatelier, Signor Giolitti, and others.

As regards our own country, I venture to say that the host of Addresses and Papers, some forty in all, are unique, and of a most valuable nature. The Addresses include those to be presented by Sir Herbert Jackson, Mr. Barnard, Prof. Cheshire, and Prof. Conrady, each of them meriting commendation of the highest kind. As regards the authors of the large number of papers presented, it is not possible to mention here the names, for they are so numerous, but it can be added that the general standard of the papers is exceedingly high, and we thank those many contributors most heartily for the trouble and pains they have taken in preparing their communications.

May I say, too, on your behalf, how extremely grateful we are to the authors of the Addresses and Papers, also to the Exhibitors and the many others who have worked with such energy to make the Symposium not merely, I trust, a success, but one from which will spring benefits, both scientific and practical, of the highest order.

I wish to add one word with regard to the most valuable historical collection submitted by the Education Department. I refer to that from the Science Museum, South Kensington. I also take this opportunity of offering our heartiest congratulations to Sir Francis Ogilvie, the Director of that Museum, upon his recent well-deserved Knighthood.

We have, too, with us this evening many important Members and visitors who have done much for the microscope. Amongst them is my friend Dr. J. E. Stead, who has greatly helped metallography. I am sure you will all be glad to learn that he is in May next to become President of that important body, the *Iron and Steel Institute*. We wish him health and strength and a most successful term of office.

I am sure I shall be excused for referring to family matters. Of course, as family matters are, it is strictly private, but as we are one big family to-night we should like you all to share in our joys. It is not often that after quite a considerable interval of time it is possible to bring together the Founders of a Society. The changes and chances of this mortal life step in and sadly break continuity, but in this special case I am glad to tell you we have present with us this evening, with one unavoidable exception—and, happily, this is not owing to the member in question not being in the land of the living—all the Founders of the Faraday Society. I refer to Mr. Sherard Cowper-Coles, Mr. W. R. Cooper, Prof. F. G. Donnan, Dr. F. M. Perkin, Mr. Alexander Siemens, Mr. James Swinburne

and Mr. F. S. Spiers. It must be a great satisfaction to them to see this magnificent meeting, as one of the fruits of their labours in the past; that is, in seeing the Society they founded, aided by the sister Societies, in the earnest set purpose of assisting our Empire in this important question of improving our resources in optical matters. All honour to the men mentioned, and I am sure that I shall be voicing your feelings in offering them our heartiest congratulations.

Whilst this is a meeting of the "Micro-Intellectuals," may I now descend to earth and remind you that our full programme has its drawbacks. We have the time limit to consider, and I beg that this be borne in mind. If I have occasionally to use the closure it will not be because the words being uttered are not considered words of wisdom, but that the evening is not long enough. I will now try to set the example by making my own remarks as brief as possible.

Sir Robert Hadfield then presented the following "Introductory Address," to the salient features of which he briefly drew attention.

INTRODUCTORY ADDRESS

By SIR ROBERT HADFIELD, Bart., D.Sc., D.Met., F.R.S.,

President of the Faraday Society.

SECTION I.—INTRODUCTION.

As the result of some suggestions I made several months ago to the Council of the Faraday Society, it was arranged to hold this present Symposium on "The Microscope and its Applications." The Royal Microscopical Society (Mr. J. W. Barnard, President); the Optical Society (Professor F. J. Cheshire, President); and the Photomicro graphic Society (Mr. F. Martin Duncan, President) all most cordially approved and agreed to co-operate with us. In view of the fact that the objects of the Faraday Society, as set forth in its Constitution, are not only to promote the study of Electrochemistry, Electrometallurgy, Physical Chemistry and Kindred Subjects, but also Metallography this Symposium is specially appropriate. It is only, or at any rate chiefly, the last named Branch of Research—Metallography—my own remarks are meant to cover, that is, I do not pretend in this Address to deal with the Work of the Microscope as employed by the Geologist, the Zoologist, the Biologist, and other Branches.

During the preparation of this Address I found the interesting frontispiece of the Book by George Adams, "ESSAYS ON THE MICROSCOPE." This was published July 1st, 1787, and contains a Practical Description of the Most Improved Microscopes, revised by Frederick Kanmacher, F.L.S., 1798. I thought this illustration particularly appropriate to form the frontispiece to this present Address of mine. The quaint wording at the foot of the Engraving

"Truth discovering to Time, Science instructing her Children in the Improvements on the Microscope,"

well describes the object of our present Symposium.

As regards the modern application of the Microscope including that to Metallography, below is a portion of the preface to Monsieur Félix Robin's Work "Treatise on Metallography," contributed by Professor F. Osmond, who did so much for Metallurgy, and from

whose work we are to-day greatly benefiting. Robin has, alas, himself passed away during the Great War, gloriously devoting his life on the Field of Battle on behalf of his Country. I make no apologies for referring to this tribute to the Metallographist and for quoting in full the wise words of Osmond. These are well worthy of consideration to-day, and the reasons given by him will, I trust, cheer many an author and many a worker in the fields of research.

Osmond said: "To write a treatise on a branch of Science in process of active development is an arduous task, especially when the author is not a professor and the book not the natural synthesis of the course. It is also a thankless task, for the work of to-morrow will amplify and correct that of to-day. In a few years' time, too, the old edifice must be rebuilt because the new generation no longer deems it sufficiently comfortable in its old form. We ought, therefore, to be indebted to those who have the courage—which I have always lacked—to collect and collate scattered material. Those who continue the work are thereby saved the trouble of lengthy visits to libraries and the search for documents of sometimes questionable value disseminated in the periodicals of all civilised countries. But M. Robin's book is not a mere compilation. The author, whose numerous papers have evoked the attention of, and have been the subject of numerous awards by, the British Iron and Steel Institute and others, has been working whole-heartedly for some years past in the direction of extending our knowledge of Metallography and its kindred Sciences. His contributions to this Science have been most useful, and he is thus in a position to enrich the present treatise by his personal experience and minute observations, to the great benefit of those who will follow him."

"*La science est un pays plein de terres désertes ;*
"*Tous les jours nos auteurs y font des découvertes.*
"*Mais ce champ ne se peut tellement moissonner,*
"*Que les derniers venus n'y trouvent à glaner.*"

Work of the Various Societies taking part in this Symposium.

The Faraday Society.—Turning to the work of each of the Societies taking part in this Symposium, I deal with that of the Faraday Society in a separate paper presented to this Symposium, entitled "The Work of the Faraday Society and a brief Reference to Michael Faraday." I will therefore not add anything further here. (*See Appendix II, p. 254*).

Royal Microscopical Society.—The Royal Microscopical Society was established in 1839. The late Dr. H. C. Sorby, F.R.S., of Sheffield, the Founder of Modern Metallography and of whom a portrait is given in Fig. 1, was President of this Society in 1876 and 1877. The famous Microscopist, Dr. W. Dallinger, F.R.S., of whom a portrait is given in Fig. 2, and who lived in Sheffield for a number of years, was also President, in the years 1884-7.

Amongst other Past Presidents of this important Society have been Sir Richard Owen, 1840; Edwin Lankester, 1858; John Thomas Quekett, 1860; Lord Avebury, 1907; Sir Edwin Ray Lankester, 1909; Prof. H. G. Plimmer, 1911; and to-day Mr. J. E. Barnard.

It was in November, 1866, that Mr. Secretary Walpole notified the President that Her Majesty had been graciously pleased "to command that the Society shall be styled the Royal Microscopical Society."

Singular to say, notwithstanding his early work in 1857-1863, Dr. Sorby, even in his own Presidential Addresses in 1876-1877 to the Royal Microscopical Society, made no reference to the use of the Microscope for Metallurgical Research. Apparently, he himself had not then applied his method of study, but the germ was there waiting to be developed. Professor W. G. Fearnsides has pointed out in his interesting account of Sorby's lifework in the first Sorby Lecture delivered before the Sheffield Society of Engineers and Metallurgists in 1914, "On some Structural Analogies between Igneous Rocks and Metals," that it was in the year 1885, by the use of Lenses of high resolving power and comparatively large magnification, Sorby first saw the true composite nature of the "pearly constituent" of Steel as an aggregate of parallel plates. This discovery was the earliest recognition of the formation of crystals from a solid solution, and may be regarded as the crowning achievement of his microscopical research. He announced this discovery to the Iron and Steel Institute in 1886, and in 1887 presented to the same Institution his historical Paper on "The Microscopical Structure of Iron and Steel," which gave a full account of his methods and the results he had obtained.

A well-known American writer, in a biographical sketch of Sorby published in "The Metallographist" for April, 1900, stated: "Whatever has been accomplished since in Microscopic Metallography has been done by following in his footsteps. To Dr. Sorby, and to him alone, is due the pioneer's honour."

I had at first intended to include in this Address my remarks regarding the great work performed by Sorby for "The Metallographist." In view, however, of the importance of the subject, and that some of our younger members may not be aware of the facts, I have thought it best to embody and present these in a separate short communication entitled "The Great Work of Sorby."

Optical Society.—As regards the Optical Society, which now has its Headquarters at the Imperial College of Science and Technology at South Kensington, this was founded in 1899, its first President being Mr. W. H. E. Thornthwaite, F.R.A.S. Subsequent Presidents have been Dr. R. M. Walmsley, Professor Silvanus Thompson, Dr. W. Rosenhain, Sir Richard Glazebrook, Sir David Gill, and to-day Professor Cheshire, C.B.E., who did such excellent work in the War.

Photomicrographic Society.—The Photomicrographic Society was founded in 1911 by a small band of Microscopists and Photographers, including Fellows of both the Royal Microscopical and Photographic Societies, having for its objects, to quote from its Rules, "the study

of Photomicrography and the discussion and demonstration of any subjects of interest concerning it." From the first the Society was a success, as evidenced by continual increase of Membership, and this is perhaps due to the wide field in Research, Engineering, Natural History, Industrial and other Processes, in which the Microscope is essential. This is also shown in the diverse nature of the subjects in which individual members are specially interested, but who alike have to record their observations by Photography. Others again are interested purely in the optical equipment of the Microscope and the special problems presented to the photomicrographic worker. The essential importance of correct microscopic technique, especially proper illumination to obtain a correct image, has always been recognised, and great attention has been paid to the mechanical side, as shown by apparatus designed and built by several members and exhibited from time to time.

Mr. F. Martin Duncan now occupies the Presidential Chair, and Mr. J. E. Barnard was President in 1915-16. A Medal is awarded annually, for the best results in Photomicrography from both the microscopical and photographic point of view.

The Society meets twice monthly at King's College, and has papers on the many subjects in which the use of the Microscope is essential, together with other meetings of a less formal character for discussion, exhibition of photomicrographs, and apparatus connected with Photomicrography.

For the foregoing information I am indebted to the Honorary Secretary and Treasurer, Mr. J. G. Bradbury, who has done so much good work on behalf of this useful Society.

British Science Guild.—The Committee on the Microscope appointed by this Body, with its Chairman, Dr. Walmsley, have also been kind enough to give much useful help with regard to our Symposium.

It will be seen therefore that the Faraday Society has been successful in enlisting the co-operation and aid of the various special Societies who are also immediately interested in improving Research Work in Microscopy.

OBJECTS OF THE SYMPOSIUM.—The objects of the Symposium are :—

(*a*) Improvement in the technique of the Microscope itself, including its manufacture.

(*b*) Improvement in Lenses including Eye-pieces and Objectives of High Power.

(*c*) Improved application of the Microscope for Research in Ferrous and Non-Ferrous Metallurgy.

With these objects all will be in agreement, and if as a result of this Symposium they are successfully carried out and attained, as I am confident will be the case, our gathering will be not only

noteworthy, but will prove to be of great service to those interested, in our own Country, America, and elsewhere.

PRESENT AND FUTURE WORK.—As regards the particular direction in which Metallurgists should look in the future for further help from the Microscope, may I suggest that one of the objects we ought to have in view should be to obtain increased knowledge from examinations at higher magnifications, that is to say, 5,000, 8,000 and still higher. This may seem ambitious, and I may be wrong as to the value of the knowledge to be so obtained, but I hope not. If there is anything in my belief, a wide vista opens out for further Research Work.

I am contributing along with Mr. T. G. Elliot, F.I.C., a special paper on this important aspect of the subject, entitled "Photomicrographs of Steel and Iron at High Magnification," which I hope will be of interest to our members.

In the past both in England and in America there has been far too much dependence on Germany and Austria for the supply of the best type of Microscope, including constructional details, and high-quality Objectives and Eye-pieces. It is most desirable that in future this situation should be avoided. Forewarned is forearmed, and every possible means must be taken in a fair and open manner to remedy this situation by private enterprise and research, and if necessary by Research Associations aided by the grants allocated by Parliament for such purposes.

To show that it is of the highest importance that this Country should be independent of foreign aid in its supplies of this nature, it may be added that had it not been for the enterprise of just one British Firm with regard to the supply of Optical Glasses at the outbreak of War, we might have been absolutely stranded in the supply of the necessary products, both for apparatus and glassware, so essential in sighting and other instruments of observation used in Modern Warfare.

By these remarks I do not wish to disparage the work of those who until recently have been Enemies, and who in the past wisely equipped themselves by means of Apparatus and Appliances of all kinds as well as by encouraging scientific development. Good work proceeding from any nationality stands fast for all time. Let us, however, now learn the lesson and benefit from the experience gained by us during the War at such bitter cost. It has to be admitted that our Instrument Makers were then necessarily largely employed in other directions and were unable to cater for the requirements of the Microscopist. They could not therefore devote the time so essential for improving not only the mechanical but the optical details of the Microscope, including its Objectives and Eye-pieces. Notwithstanding the many advances made during the War by the Chemist, the Electrician, the Metallurgist, the Engineer, and others, no special claim can be made that much progress has been made by the Microscopist. As far as can be gathered, the methods and appliances now used do not show great advance on those prior to the War. In saying

that it is not meant to indicate that knowledge has not been accumulated and that, for example, we shall in the future be dependent upon foreign supplies as in the past; it is hoped quite the contrary. It is one of the main objects of this Symposium to bring forth and prove that all these requirements can and will be met by the Anglo-Saxon, or at any rate that this will be possible in the immediate future.

It should be added that there stands out very prominently in this connection the important work done on behalf of Glass Technology by Sir Herbert Jackson, K.B.E., to whom we are greatly indebted, and who will give us an important Address this evening.

Reference should also be made to the excellent work carried out on this subject by the National Physical Laboratory, where systematic work on the attack of various refractory bodies by molten glass under carefully standardised conditions has been continued, together with work on the production of crucibles increasingly resistant to such attack. Progress has been made in the application of fused zirconia as a lining for crucibles. In the course of this work special phenomena have been observed in the attack which occurs in some cases at the bottom of the crucible, and in others, at the level of the surface of the glass. These phenomena have been studied by means of experiments on the mode of solution of such substance as wax, naphthaline and plaster-of-paris in ordinary solvents at room temperature where the phenomena could be observed. Most of the features met with in the attack of molten glass on crucibles have been reproduced in such experiments, and a method of preventing the worst features of such attack has been tried and found successful in the model experiments. In addition reference should be made to the valuable work done by the Society of Glass Technology at the University of Sheffield, in which Dr. W. E. S. Turner, the honorary secretary, has played so important a part.

It is certainly most necessary that we should not be behind but abreast of our Foreign competitors in the making of Microscopes and Lenses or their use. One of the prominent objects in holding the Symposium is to arouse still more interest in the advancement of this work.

SECTION II.—HISTORY OF THE MICROSCOPE.

Ancient Times to 1600 A.D.

If the Microscope is considered as an Instrument consisting of one Lens only, it is not at all improbable that it was known to the Ancients, and even to the Greeks and Romans. The minuteness of some of the pieces of workmanship of the Ancients would appear to indicate that they must have been executed by the use of Magnifying Glasses. Many passages in the Works of Pliny, Plutarch, Seneca, and others clearly indicate this.

There is reason to believe that the magnifying power of transparent media with convex surfaces was known very early. The convex Lens of rock crystal was found by Layard among the ruins of the Palace of Nimrod. Seneca describes hollow spheres of glass filled with water as being mainly used as magnifiers. It is practically certain that

the perfect gem cutting of the Ancients could not have been attained without the use of magnifiers.

In the Book " Essays on the Microscope " by George Adams, Mathematical Instrument Maker to His Majesty (1787), being " A Practical Description of the Most Improved Microscopes," which was one of the Standard Works at that time, Adams said : " It is generally supposed that Microscopes were invented about the year 1580, a period fruitful in discoveries. The honour of the Invention is claimed by the Italians and the Dutch ; the name of the Inventor appears, however, lost."

With regard to the many interesting facts relating to the early History of the Microscope, two valuable contributions have been made by Dr. Charles Singer, M.D., " Notes on the Early History of the Microscope " read before the Royal Society of Medicine in 1914, and " The Dawn of Microscopical Discovery," before the Royal Microscopical Society in 1915.

In giving the following information I have taken the liberty of freely making use of the valuable Researches of Dr. Singer, who points out that there have been three main epochs in the History of Microscopical Discovery. There was the Pioneer Period, extending to about 1660, the Classical Period, covering half-a-century or more from about 1660, and including the work of the great Microscopists, Hooke, Grew, Malpighi, Leeuwenhoek and Swammerdam, and finally the Modern Period, dating from the Optical Discoveries of Newton.

The earliest microscopical observation known is stated by Dr. Singer to be of Seneca (circa A.D. 63) who in his " Quæstiones Naturales " said that " Letters, however small and dim, are comparatively large and distinct when seen through a glass globe filled with water."

The properties of curved reflecting surfaces, and even to some extent of Lenses, were known to the ancients, and to some mediæval writers, such as Roger Bacon. The invention of convex spectacles is attributed to Salvino d'Amarto degli Armata, of Florence, and to Alessandro de Spina, of Pisa, about the year 1300, and these aids to vision were familiar to many throughout the fourteenth, fifteenth and sixteenth centuries. During this period the optical properties of Lenses were investigated by the penetrating genius of Leonardo da Vinci (1452–1519) and by the mathematical skill of Maurolico (1494–1575), while convex spectacles must have been on the nose of many a careful illuminator of manuscripts.

Up to this time Dr. Singer points out there is no single instance on record of these glasses having been used for the investigation of nature and that even the many illuminated manuscripts of the fifteenth and sixteenth centuries, especially of the Flemish school, do not suggest the use of magnifying glasses.

The first illustrated publication, for which there is evidence of the use of a magnifying glass, appeared in the year 1592 at Frankfort, bearing the name of George Hœfnagel (1545–1600). The volume consisted of a series of plates engraved on copper, illustrating common objects of nature, but drawn with exceptional skill and minute accuracy. Some few of these drawings revealed enlarged details which would

have been hardly distinguishable to the unaided eye. These remarkable figures are stated to have been the work of Hœfnagel's son, Jacob (1575).

It must be remembered, however, that the occasional use by a naturalist of a simple Lens of low magnifying power could have but little influence on the advance of knowledge. It was not until the Classical Period with the invention of Lenses of very short focus that the simple Microscope became a valuable means of Research. In the Pioneer Period it was rather the discovery that Lenses could be combined into the Telescope and the Microscope that gave the first stimulus to investigation. These compound instruments were invented about the year 1610.

1600 to 1700 A.D.

The Dutchman Zacharias, miscalled Jansen, and his son made Microscopes before the year 1619. It was he who, whilst still a lad, had worked with his father, who was a spectacle maker, and appears to have discovered accidentally the principle of a Telescope by placing two Lenses together in a tube. The invention of the Microscope followed about that time, though the exact date is unknown. In the year 1619, Cornelius Drebbel, of Alkomar, brought a Microscope which was made by the Jansens with him into England and showed it to William Boreel, who was Dutch Ambassador to France, and eventually to England. It is, however, added that Drebbel's instrument was not strictly what is now meant by the Microscope, but was rather a kind of Microscope–Telescope, somewhat similar in principle to certain apparatus described by Mr. Aepinus in a letter to the Academy of Sciences, St. Petersburg. This was formed of a copper tube six feet in length and one inch in diameter. On the other hand, Dr. C. Singer, in his interesting Paper on "The Historical Aspect of the Microscope," does not think this was the case.

A portrait of Jansen is given in Fig. 3. A photograph is also given of Hans Lipperhey (Fig. 4), who is described as the inventor of the second Microscope, Jansen being referred to as the inventor of the first one, that is of the special type described probably in the beginning of the Seventeenth Century.

Dr. Hooke, the author of the famous "Micrographia" in 1665, described means of utilising small drops or globules of glass in a Microscope, and said that by means of this he had been able to distinguish the particles of bodies not only a million times smaller than the visible points, but even to make these visible whereof millions of millions would hardly make up the bulk of the smallest visible grain of sand; so prodigiously do these exceedingly small globules enlarge our prospect into the more hidden recesses of Nature. Di Torre of Naples also largely made use of these globules for his well-known investigations.

As regards Hooke's Book referred to, it may be interesting to give a facsimile (Fig. 5) of the title page as it appeared in 1665. Hooke was a Fellow of the Royal Society, and a facsimile of his signature as it appears in the famous "Roll Call of Fellows" is given at the foot of the front page, in Fig. 5.

As an interesting example of the examination done by Hooke in 1664, and simple as this may seem now, I give in Fig. 6 the result of an investigation he carried out on the point of a small needle, which to use his own words, was

made ſo ſharp that the naked Eye is unable to diſtinguiſh any of its Parts. This, notwithſtanding, appeared before his Microſcope as in the Figure at *a a*, where the very Top of the Needle is ſhewn above a Quarter of an Inch broad; not round or flat, but irregular and uneven.

The whole Piece we have here the Picture of, (according to the Scale given with it) is little more than the twentieth Part of an Inch in Length, and appeared to the naked Eye exquiſitely ſmooth and poliſhed; but, as ſeen by the Microſcope, what a Multitude of Holes and Scratches are diſcovered to us? How uneven and rough the Surface! how void of Beauty! and how plain a Proof of the Deficiency and Bunglingneſs of Art, whoſe Productions when moſt laboured, if examined with Organs more acute than thoſe by which they were framed, loſe all that fancied Perfection our Blindneſs made us think they had! Whereas, in the Works of Nature, the farther, the deeper our Diſcoveries reach, the more ſenſible we become of their Beauties and Excellencies.

But to return to the Object now before us; A, B, C, repreſent large Hollows and Roughneſſes, like thoſe eaten into an Iron-Bar by Ruſt and Length of Time. D is ſome ſmall adventitious Body ſticking thereto by Accident.

b. b. b. ſhew the End where this ſmall Piece of Needle was broken off, in order to take the better View of it.

As ſharp as a Needle is a common Phraſe, whereby we intend to expreſs the moſt exquiſite Degree of Sharpneſs; and, indeed, a Needle has the moſt acute Point Art is capable of making, however rude and clumſy it appears when thus examined. But the Microſcope can afford us numberleſs Inſtances, in the Hairs, Briſtles, and Claws of Inſects; and alſo in the Thorns, Hooks, and Hairs of Vegetables, of viſible Points many Thouſands of times ſharper, with a Form and Poliſh that proclaim the Omnipotence of their Maker.

Another investigation was carried out by Hooke on the "edge of a razor," and to quote his words,

Figure repreſents the Edge (about half a Quarter of an Inch long) of a very ſharp Razor well ſet upon a good Hone, and ſo placed between the Object-Glaſs and the Light, that there appeared a Reflection from the very Edge, which is ſhewn by the white Line *a*, *b*, *c*, *d*, *e*, *f*.

When we ſpeak of any thing as extremely keen, we uſually compare it to the Edge of a Razor; but we find, when examined thus, how far from Sharpneſs even a Razor's Edge appears: That it ſeems a rough Surface, of an unequal Breadth from ſide to ſide, but ſcarce any where narrower than the Back of a pretty thick Knife: That it is neither ſmooth, even, nor regular; for it is ſomewhat ſharper than elſewhere at *d*, indented about *b*, broader and thicker about *c*, unequal and rugged about *e*, and moſt even between *a*, *b*, and *e*, *f*, though very far in any Place from being really ſtraight.

The Side immediately below the Edge, and what the naked Eye accounts a Part of it, *g*, *h*, *y*, *k*, had nothing of that Poliſh one would imagine Bodies ſo ſmooth as a Hone and Oil ſhould give it; but was full of innumerable Scratches croſſing one another, with Lines here and there, more rugged and deep than the reſt, ſuch as *g*, *h*, *y*, *k*, *o*, occaſioned probably by ſome ſmall Duſt falling on the Hone, or ſome more flinty Part of the Hone itſelf.

The other Part of the Razor *L L*, which had been poliſhed on a Grind-ſtone, appeared like a plowed Field, full of Ridges and Furrows.

The irregular dark Spot *m*, *n*, ſeemed to be a little Speck of Ruſt; corroſive Juices generally working in ſuch a manner.

This Examination proves, how rough and unſeemly (had we microſcopic Eyes) thoſe Things would appear, which now the Dulneſs of our Sight makes us think extremely neat and curious: And, indeed, it ſeems impoſſible by Art to give a perfect Smoothneſs to any hard and brittle Body; for *Putty*, or any other ſoft Powder, employed to poliſh ſuch Body, muſt neceſſarily conſiſt of little hard rough Particles, each whereof cutting its Way, muſt conſequently leave ſome kind of Furrow behind it. In ſhort, this Edge of a Razor, had it been really as the Microſcope ſhews it, would ſcarce have ſerved to chop Wood, inſtead of ſhaving a Man's Beard.

In the Bibliography accompanying the present Address will be found reference to some of the writings of other early workers with the Microscope. For example, Antony van Leeuwenhoek, born at Delft in 1632, constructed the first practical microscope and established the art of properly grinding and polishing the Lenses.

Leeuwenhoek was offered, and accepted, the post of Chamberlain of the Sheriff of the town of Delft, worth £26 annually, and held this for 39 years. In February, 1680, he was made a Fellow of the Royal Society. Although he never came to London, the Diploma of Fellowship was sent to him in a silver box, having the Arms of the Society graven on it. An interesting account of his life is given by the President of the Royal Microscopical Society, Professor H. G. Plimmer, F.R.S., in his Presidential Address in 1913.

Leeuwenhoek did wonderful work with his simple or singular Microscope. The largest magnification he obtained was about 160 in one of his Microscopes: his twenty-six other Microscopes varied from 40 to 133 magnifications. With this simple instrument, as Professor Plimmer points out in his address, Leeuwenhoek discovered a new world, in fact new worlds, for us. He saw for the first time Infusoria, Rotifers, and Bacteria. It is interesting to note in this connection that Charles Darwin took no compound Microscope, but only a simple one, with him on his famous "Beagle" Voyage.

So important was Leeuwenhoek's work that I give a portrait of him (Fig. 8).

In the paper "On the Construction of the Compound Achromatic Microscope" by Charles Brooke, M.A., F.R.S., read before the Royal Institution of Great Britain, March 10th, 1854, he states that the first compound Microscopes on record, such as that of P. Bonnani, about 1697, which was placed horizontally, and that of J. Marshall in the beginning of the eighteenth century, which was vertical, were furnished with central condensers. In later years the development of the illuminating apparatus has by no means kept pace with that of the ocular portion of the Microscope, though scarcely of less importance in attaining the highest perfection in the vision of microscopic objects.

On the authority of Adams, the first three compound Microscopes were said to be those of Hooke, Eustachio Divinis and Philip Bonnani. An account of Divinis' Compound Microscope was read before the Royal Society in 1668 (Philosophical Transactions No. 42).

It must be borne in mind, too, that the progress made in the science of Optics was largely aided by the great work of Sir Isaac Newton, Delavel and Herschel.

1700 to 1800 A.D.

It is stated by Roberts-Austen also in his "Metallurgy" that the Microscope was first applied to the Examination of Iron and the first records go back to 1722 when Réaumur described the structure of Chilled Castings under the Microscope. François in 1832 took

the interesting case of the direct reduction of Iron from its Ores, and followed the successive changes by the aid of the Microscope. Roberts-Austen also claims that: "If to these analytical data observations under the Microscope with a magnification of 300 to 400 diameters be added, it is seen that ordinary Iron is merely a metallic network with a close-grained tissue, with submerged scoriaceous opaline, sometimes sub-crystalline, portions, and with little globules and metallic grains ranged in every direction. Sometimes nests of translucent prismatic and bacillary crystals, with metallic portions adhering, are noticed hidden in the paste. These are the grains of Steel which can be made to disappear by heating."

Roberts-Austen thought that Modern Metallography owed some of its development to the use made of it in the Study of Meteoric Irons, also that it is quite possible, as has often happened in the History of Science, that there are several independent origins.

From 1800 A.D. Onwards.

It is interesting to note that in 1808, Widmanstätten oxidized a heated specimen and took polished sections of meteoric iron, thus originating what is now termed "Metallography."

Sorby in 1856 founded Petrography, employing sliced sections in connection with the Microscope for the study of rocks, the structures of which are in some cases analogous to those of metallic alloys. In the year 1864 he made an examination of meteoric iron, also studying various metallurgical products; while in 1885 he discovered Pearlite. When Sorby proposed for the first time to submit a specimen of rail, which had broken and caused an accident, to a microscopic analysis, he was told that it was an insane idea. Sorby's method has since been invaluable for this very purpose—in fact in this Country and in America and elsewhere tens of thousands of photomicrographs have been prepared in connection with the investigation of broken and other rails.

Mr. J. Stuart—himself a veteran of some eighty-four years—of the Clapham Common Optical Works of Messrs. Ross, told me recently that in the 'seventies of the last Century he had repeated visits from Dr. Sorby, who brought various specimens of Steel for examination under the Microscope. Mr. Wenham, Vice-President of the Royal Microscopical Society and the Inventor of the Binocular Microscope, as well as of other microscopical apparatus, was at that time working with Messrs. Ross as their Scientific Adviser. Mr. Wenham was also interested in the study of the structure of steel and had many conversations with the late Dr. Sorby, in fact, constructed for him a high power Binocular which Mr. Stuart believes was the first to be used in connection with the examination of Steel.

Incidentally it may be useful to refer to the fact that the invention of the Oil Immersion Objective was not, as is often imagined, of foreign origin, but was originated by Mr. Wenham in 1870, that is, six or seven

years before Oil Immersion Objectives were constructed at Jena by Professor Abbe. In a Paper read by Mr. Wenham, entitled "Remarks on High-power Definition," at a meeting of the Royal Microscopical Society in June of that year 1870, he says: "Of course there is no optical advantage attendant upon the use of water in immersion lenses. If a medium of the same refractive power as the glass were to be employed the result would be better. Water, having a low refractive index, an adjustment is required for each thickness of cover, and a difference of adjustment is not so marked and sensitive as in the ordinary dry objective; but if a medium of similar refraction to the glass were to be used, no adjustment would be required for any thickness of cover, supposing the test objects to be mounted thereon (which they generally are), for, in fact, we should then view them all with a front of the same thickness—considering the cover, the front lens and the interposing medium as one."

In addition to reading this Paper, Mr. Wenham exhibited at the same Meeting an Oil Immersion Lens using Cedar Oil and an illuminated object showing great brilliancy. It appears, however, he did not at the time realise that his Oil Immersion could have yielded the great numerical aperture which it afterwards gave in the hands of Professor Abbe.

Another interesting point is the fact that Andrew Ross, the founder of the firm of Messrs. Ross, discovered the system of the Collar Adjustment for Water Immersion Lenses and that Mr. Wenham was the Discoverer of the Oil Immersion which required no Collar Correction.

To show how little was thought of the Microscope as a scientific instrument in connection with the study of Iron and Steel, reference may be made to a Book which I have often found useful, namely, Ferdinand Kohn's "Iron and Steel Manufacture," published about 1868 and based upon a series of valuable articles on "The Manufacture of Iron and Steel," which appeared in "Engineering." In this book Kohn says, in the chapter devoted to "Steel under the Microscope," "An experienced steelmaker can estimate very closely the ferrous quality, chemical composition, tensile and compressive strength of any sample of steel, and even the mode of treatment which it has undergone, by looking at its fracture under the Microscope."

It appears, however, this only meant a small hand Microscope. The following are the words: "A Pocket Microscope of this kind ought to be the companion of every man interested in Steel or Steel Manufacture. Lenses of the usual kind, even if piled up in sets of three or four, are entirely insufficient. The Lens must be of a very small focus, and properly achromatic. A little practice is sufficient to enable the user to "see" through this Lens; but it is, of course, not quite so easy to learn the meaning of what is seen, and to estimate from the appearance the quality of the steel inspected."

Special reference was made to some investigations then being carried out (1868) by Mr. Schott, the Manager of Count Stolberg's Foundry at Islenburg, upon the appearance of liquid and solidifying Cast Iron under the Microscope. Mr. Schott contended that each

crystal of iron is a double pyramid upon a flat square base, and that the ratio of height to base of the pyramid is proportional to the carbon content. In Cast Irons and hard Steel the crystals approach the cubical form, whilst in Wrought Iron the pyramids are almost flattened down into leaves. In addition the quality of a steel is shown by the arrangement of the crystals. The highest quality of steel has its crystals in parallel positions with their axes in the direction of the pressure exerted on them in working. An examination of the fracture of a good steel in reflected light shows a series of parallel streaks on the surface, whereas in a bad steel several systems of parallel lines can be seen.

The presence of segregated material and size of the grain can also be seen under the Microscope. The absence of the former and the fineness of the latter indicate good material.

The qualities of parallelism of the material and fine grain seem to be due to different causes. The former seems to be caused by the action of heat, and repeated melting is the great panacea in this respect, whilst the latter is brought about largely by working the material; on the other hand working the material seems to prove that parallelism and high temperature bring about the coarsening of grain.

Singular to say, Kohn does not make a single reference to the work of Sorby, which was evidently then only known by few people.

Dr. Dallinger, F.R.S., who resided many years in Sheffield, gave in the Journal of the Royal Microscopical Society, Vol. 17, 1877, page 224, a "Note on the Ultimate Limit of Vision" as applied to modern Microscopical Lenses. He reasoned that mathematicians of the first order, notably Helmholtz, had concluded that the limit of vision had been reached and that the Optician could practically give no further aid. Dr. Dallinger considered that the limit marked out was about the one-hundred-and-eighty-thousandth of an inch, and added that he did not consider the limit of visibility had been reached.

Dr. Sorby in a Paper on the "Limit of the Powers of the Microscope" to the same Society in 1875 referred to an experiment of Dr. Royston-Pigott which showed that the smallest visual angle he could ever distinctly appreciate was a hole $1\frac{1}{4}$ in. in diameter at a distance of 1,000 yards, which corresponds to about 6 seconds of arc. This visual arc in a Microscope magnifying 1,000 linear would correspond to about three-millionths of an inch.

Tchernoff took up the study of crystallization of Steel, his work being brought before this Country by the late Sir William Anderson. In 1878 Wedding studied Steel by the aid of the Microscope. The work of these investigators caused rapid increase of interest in this subject.

Dr. Martens of Berlin rendered further valuable services, in fact was one of the first to introduce the practical study of Iron and Steel by Metallography. Martens' work commenced about 1878, when he published notes on the Microstructure of Steel.

In 1880 the use of the Microscope was introduced at Le Creusot Works, and important investigations by Professors F. Osmond and J. Werth were started, and from that date were carried out on the lines first indicated by Dr. Sorby.

In his Book on "How to Work with the Microscope," 1880 edition, Dr. Lionel S. Beale, F.R.S., a former President of the Microscopical Society, gave an interesting statement as to the methods of preparing specimens when examining the Microstructure of Iron and Steel.

Roberts-Austen in his book already quoted does just credit to the important work carried out in this Country by Professor J. O. Arnold, F.R.S., who had the great advantage of being in touch and collaborating with the late Dr. H. C. Sorby—in fact the mantle of Sorby descended upon him. Arnold commenced his work about 1890, and the World is under a debt of gratitude for the important results obtained by his valuable labours in this field of research.

Professor Arnold tells me that his first association with Sorby was about 1885 at the Natural Science Section of the Literary and Philosophical Society in Sheffield, where I also met him. When Arnold was appointed to the Chair of Metallurgy in the University of Sheffield in 1889 he persuaded Sorby to resume his micrographic work on Steel in conjunction with his (Arnold's) work on Chemical Analysis, Recalescence and Mechanical Testing, feeling sure that micro work was a vital factor, necessary to render more complete our knowledge of steel. However, Sorby stated he had so much on hand, and his eyesight was failing, that he was not able to take up the work again, but how glad he was to find that his pioneer work was considered to be helpful to Metallurgy. Sorby lent Arnold all his pioneer sections during his lifetime and in his Will left them to the Metallurgical Department of the University of Sheffield. Sorby also gave Arnold his various data and, on several occasions, went through his different sections, which, singular to say, were afterwards destined to be Arnold's for eleven years. Through the kindness of Professor Ripper these specimens are exhibited this evening.

It may be added that Sorby discovered at least five constituents of Steel, Stead three, and the Sheffield University—largely the work of Arnold himself—was responsible for many of the others now known to the World. It was also Arnold who determined the quantitative composition of Sorby's Pearlite and Hardenite.

Dr. J. E. Stead, F.R.S., also at an early date saw the great importance of this branch of investigation, and by his lucid papers and research work has greatly aided the progress of Metallography.

Osmond's unrivalled research work further established modern Metallography in 1895. He discovered successively the constituents of Quenched Steel and accurately determined the critical points of Iron. Moreover he had, along with Werth, previously described the cellular structure of metal. As Sauveur says, if Sorby was the pioneer of Metallography and Tchernoff its father, Osmond has been its torch-bearer.

The work of the Nomenclature Committee on Metallography is useful to those interested in this subject, and will be found in Vol. I

of the Iron and Steel Institute Journal, 1902, comprising some twenty-three pages in its Glossary of Terms.

In addition to the main Societies, who have assisted in developing Microscopy, have been the following: The Sorby Scientific Society, comprising The Sheffield Microscopical Society, and The Sheffield Naturalist's Club, which were amalgamated on January 1st, 1918; the Quekett Microscopical Club; the Dublin Microscopical Club, and the Photomicrographic Society.

Special reference may be made to the excellent work of the Quekett Club, which is probably the most active Microscopical Club in any Country. Its Headquarters are in London, and Meetings are held from time to time. The present occupant of the Presidential Chair is Dr. A. B. Rendle, M.A., F.R.S.

SECTION III.—MODERN WORK ON MICROSCOPES, OBJECTIVES AND EYE-PIECES.

Mr. Conrad Beck, F.R.M.S., many years ago did valuable work on behalf of Microscopy in his Cantor Lectures before the Royal Society of Arts, 1907, on "The Theory of the Microscope." Previous to these Lectures, Mr. John Maynall, junr., gave two excellent series of Lectures on the same subject, entitled "The History of the Microscope." before the same Society.

An able Address was read by Mr. Joseph E. Barnard, now President of the Royal Microscopical Society, in February, 1919, on "The Limitations of Microscopy." Everyone interested in this subject should read the Address, which is divided into various subjects, dealing with dimensions met with in Microscopy, a discussion on the resolving power and limits of resolution and visibility; also descriptions of the Ultra-Microscope and of experiment sillustrating its use, together with a discussion of the advantages of ultra-violet light in ordinary Microscopy; and finally suggestions as to future lines of Research.

As this paper points out, the limit of resolution may be said to have been reached when it is not possible to distinguish the details of the specimen under examination. The limit of visibility is, however, lower than this, for, although no detail can be seen, the specimen can be made visible as a spot in the field of view.

The question of Resolution is touched upon, from which it appears that under the most favourable circumstances, the practical limit is reached when objects in a row are about ·20 micron (1/50,000 cm.) apart. If the body is less than this size under the best microscopic conditions now available no detail can be distinguished.

The Ultra-Microscope shows the presence of much smaller dimensions than those mentioned above, that is, as bright specks on a dark background, but it shows none of the internal features, and no matter what the shape or nature of the object under view, it always appears circular. The smallest particle observable, that is, in the Ultra-Microscope, is that of colloidal gold, about 5 micromillimeters (1/2,000,000 cm.) in diameter. Thus the Ultra-Microscope can distinguish particles about forty times smaller than those which can be resolved under the ordinary Microscope.

Mr. Barnard showed in his Address that whilst the resolving power of a given instrument depends upon its design, it also depends upon the wave-length of the light used to illuminate the object under examination. Thus, if the object is illuminated with ultra-violet rays greater resolution still can be obtained, but, of course, the results are not directly visible and must be recorded photographically.

In a paper recently read before the Royal Microscopical Society by Colonel J. Clibborn, C.I.E., B.A., on "A Standard Microscope," it was stated by Mr. Conrad Beck that the Manufacturers of Microscopes worked under great difficulty during the War. It was not until after the 11th November, 1918, that any Microscopes were allowed to be made, all the Factories being fully engaged on other Optical Instruments. It is interesting to note, however, that these Firms are now spending large sums in manufacturing tools for the production of Microscopes, many of them to be made under the Specifications brought forward by the Committee on Microscopes appointed by the British Science Guild.

At the recent British Scientific Products Exhibition an excellent set of Exhibits was shown by the British Optical Instrument Manufacturers' Society, Ltd. Some dozen or more of the principal firms exhibited Optical Instruments and Glasses.

As pointed out in the valuable Catalogue of that Exhibition, the Optical Instrument-making Industry originated in most of its Branches in Great Britain. Newton, Young, Faraday, Clerk Maxwell and Rayleigh were the pioneers of Optics. The Achromatic Telescope was invented by Dolland, and the modern form of Achromatic Microscope by Lister. Let us therefore show that we are trying to be worthy successors of these great men.

The Optical Association has published an illustrated booklet on Scientific Instruments, which includes, with a brief description, the name of every known instrument both current and obsolete, together with a key to the British Makers. The Trade has set up a powerful Research Association and has participated in the inauguration of a Scheme of Education in Optical Engineering which is being developed by the Imperial College of Science and Technology at South Kensington. It may be mentioned that the Governing Body of the Imperial College of Science and Technology recognises the importance of Technical Optics in their relation to the needs of the Nation by providing in the Estimates of their new Scheme of Development the sum of £50,000 for expenditure on Land, Buildings and Equipment, and the sum of £4,000 annually for maintenance and carrying on the work.

Messrs. Chance Brothers commenced the manufacture of Optical Glasses in England in 1848. During the recent War they increased their output some twenty-fold. They make something like seventy different types of Optical Glasses together with a number of new types which have been recently introduced. They have rendered great service to our Empire.

Professor J. C. McLennan, F.R.S., of the University of Toronto, who was in England during the War, informed me that he had examined the Fluorite from South Africa and found it to be excellent in quality.

If this Fluorite can be used in the manufacture of Glass suitable for High Power Objectives, then the South African source of supply should be borne in mind. It is also stated that Fluorite exists in Canada, and our Honorary Treasurer, Dr. Robert Mond, is investigating this matter,

The King recently visited the Leicester Works of Messrs. Taylor and Hobson, the famous Lens experts. He there saw the instruments by which vital errors of a few millionths of an inch are avoided, and had explained to him the principles of the use in this connection of light interference, which was first studied by Sir Isaac Newton in Soap Bubbles. This Firm also make the "Aviar" Lens, which through repeated calculations and readjustments of formulæ enabled the British Photographing Aeroplanes to beat the "Archies."

In a recent number of the "Scientific American Supplement" (August 30th, 1919), a statement is made that in spite of the traditional superiority of the German Optical Industry, during the War their Lenses proved distinctly inferior to those of French and English make. The English developed superior Lenses during and under the stress of the War.

In a perfect High Power Objective known as Apochromatic, it is desirable this should give :—

(*a*) *Full Resolution.*—The resolution increases with, and is a function of, Numerical Aperture. The number of lines to the inch which an objective will resolve, if perfect, may be calculated from the Numerical Aperture.

(*b*) *Good Definition.*—Which could be magnified by a × 28 eye-piece or its equivalent without breaking down.

(*c*) *A Perfectly Flat Field.*—This is never actually obtained.

(*d*) *Freedom from Chromatic Aberration.*

Achromatic Lenses generally give good definition and their field is often somewhat flatter than in that of the Apochromats. They do not, however, give such good resolution, and are only partially colour corrected. The latter failing makes them much less efficient than the Apochromats for photographic work.

The foreign 2 mm. Objective used in the Hadfield Laboratory is a very good one of its class. Its Numerical Aperture is 1.3, and therefore according to the formula of Professor Abbe, should, if perfect, resolve about 92,000 lines to the inch. I have had photographs taken by it which show 85,000 lines to the inch clearly resolved. Its definition begins to break down with an eye-piece magnification of about 15. For an Apochromat its field is very flat, and it is in this respect chiefly that we found it superior to other Apochromats we examined. Its colour correction is apparently perfect.

It may be added that Messrs. Watsons supplied to the Research Laboratory of my firm a very excellent 2 mm. Objective.

In fact photomicrographs obtained with it seemed to possess almost equal quality to those from the best foreign objectives. Fig. 13 is a photomicrograph of a specimen of Steel taken with the above-mentioned foreign 2 mm. Apochromat, whilst Fig. 12 is a photomicrograph of the same section under exactly similar conditions, taken with the Watson 2 mm. Apochromat. It will be seen that there is very little to choose between the two photographs from the point of view of resolution and flatness of field. There is no doubt that English makers can, when required, produce Objectives at least equal in quality to the best foreign makes.

SECTION IV.—FERROUS METALLOGRAPHY.

Several excellent Works have been published on the important subject of Metallography, including "Physical Metallurgy," by Dr. Walter Rosenhain, F.R.S., which has proved of the highest service. No book, too, on the subject has been of greater use in the past than that by Professor Albert Sauveur, of Harvard University, "The Metallography of Iron and Steel." Great advances have been made since the date of its first publication, and in the second edition, 1916, it remains a standard work of reference and a model for books on a special subject —excellent matter, well printed and illustrated. The chapters are divided into Lessons, some twenty-four in all, commencing with the Study of Pure Metals; Pure Iron and Steel, up to High Carbon Percentages; the Effect of Impurities Upon Steel; Close Studies of Thermal Critical Change Points; the Effect of Annealing, Hardening and Tempering upon both ordinary and Special Alloy Steels, are considered. The Metallography of Cast Iron also receives attention. Various Apparatus for the Metallographic Laboratory, including the study of the Microscope itself, and the Apparatus, Illumination, Sources of Light, Condensers, and Photomicrographic Cameras; a description of the best Methods and Manipulations; also a most excellent nomenclature of the various Microscopic Constituents, including Austenite, Cementite, Martensite, Ferrite, Osmondite, Ferronite, Hardenite, Pearlite, Graphite, Troostite, Sorbite, Manganese Sulphide, and Ferrous Sulphide.

In words which deserve consideration by us all, so I quote them in full, Professor Sauveur in his Introduction and Remarks upon the Industrial Importance of Metallography, points out:

"Invaluable information is given by chemistry without which both the physicist and the metallurgist would be in utter darkness, but this science throws little or no light upon the anatomy of living or inanimate matter. Its very methods, which call for the destruction of the physical structure of matter, show how incapable it is to render assistance in this, our great need.

The parallel drawn here between metals and living matter is not fantastic. It has been aptly made by Osmond, who said rightly that modern science was treating the industrial metal like a living organism, and that we were led to study its anatomy, that is, its physical and chemical constitution; its biology, that is, the influence

exerted on its constitution by the various treatments, thermal and mechanical, to which the metal is lawfully subjected ; and its pathology, that is, the action of impurities and defective treatments upon its normal constitution.

Fortunately Metallography does more than reveal the proximate composition of metals. It is a true dissecting method which lays bare their anatomy—that is, the physical grouping of the proximate constituents, their distribution, relative dimensions, etc., all of which necessarily affect the properties. For two pieces of steel, for instance, might have exactly the same proximate composition—that is, might contain, let us say, the same proportion of pearlite and ferrite, and still differ quite a little as to strength, ductility, etc., and that because of a different structural arrangement of the two proximate constituents ; in other words, because of unlike anatomy.

It is not to be supposed that the path trodden during the last score of years was at all times smooth and free from obstacles. Indeed, the truth of the proverb that there is no royal road to knowledge was constantly and forcibly impressed on the minds of those engaged in the arduous task of lifting metallography to a higher level.

Its short history resembles the history of the development of all sciences. At the outset a mist so thickly surrounds the goal that only the most courageous and better equipped attempt to pierce it and perchance they may be rewarded by a gleam of light. This gives courage to others, and the new recruits add strength to the besieging party. Then follow the well-known attacking methods of scientific tactics and strategy, and after many defeats, and now and then a victorious battle, the goal is in sight, but only in sight and never to be actually reached, for in our way stands the great universal mystery of nature : what is matter ? what is life ?

Nevertheless there is reward enough for the scientist in the feeling that he has approached the goal, that he has secured a better point of vantage from which to contemplate it. The game was worth the candle, and if scientific workers must necessarily fail in their efforts to arrive at the true definition of matter, whatever be the field of their labour, they at least learn a great deal concerning the ways of matter, and it is with the ways of matter that the material world is chiefly concerned. Hence the usefulness of scientific investigation, hence the usefulness of metallography."

Among the many workers who have contributed to the progress of Metallography may be mentioned :—Arnold, Benedicks, Belaiew, Brearley, Carpenter, H. Le Chatelier, Campbell, Desch, Edwards, Elliot, Guillet, Gulliver, Giolitti, Hatfield, Honda, Howe, Humfrey, Hudson, Zay Jeffries, Law, Martens, McCance, Osmond, Portevin, Roberts-Austen, Rosenhain, Robin, Sorby, Sauveur, Stead, Thompson, Werth.

In the valuable Pocket Encyclopædia on "Iron and Steel" by Mr. Hugh P. Tiemann, B.S., A.M., with an introduction by Professor H. M. Howe, some thirty pages are devoted to Metallography. The book contains a most excellent summary of the terms used in this Branch of the Science of Metallurgy, treating of the constitution and structure of Metals and Alloys, also their relation to physical properties.

Tiemann says that originally the term Metallography concerned principally the visual examination of the structure of metals, and hence was divided into Microscopic Metallography, or, briefly, Micrometallography, where Microscopes were used to secure high magnifications, and Megascopic, Macroscopic or Macro-Metallography, where the naked eye or very low magnifications were used. The terms Microscopy and Micrography are also used.

With reference to Metallographic Examination, Tiemann considers that the methods employed may be classified into :—

(1) OPTICAL ANALYSIS: Determining the Constituents, structures, forms, appearances, etc., by the eye alone or assisted by suitable magnifying devices.
(2) THERMAL ANALYSIS: A Study of the nature of metals and alloys by means of heating and cooling curves, changes in specific heat, etc.
(3) MAGNETIC ANALYSIS: Determination of changes in nature affecting the magnetic properties.
(4) PHYSICAL ANALYSIS: Determination of the properties by the usual methods of testing.
(5) CHEMICAL ANALYSIS: Both proximate and ultimate; generally in conjunction with one of the other methods.

He defines the Microscope as follows :—

(*a*) A simple Microscope is one which has only one Lens or set of Lenses; a compound Microscope has two such systems of Lenses, one near the object (Objective) and the other near the eye of the observer (Eyepiece).
(*b*) The binocular Microscope consists of two instruments mounted to give a stereoscopic (perspective) view.

As regards the minute nature of matters forming metals and alloys of metals, an interesting statement is made by Mr. Zay Jeffries, D.Sc., Cleveland, U.S.A., who, when speaking of the ageing of the non-ferrous metal known as Duralumin, in his paper on "The Micro-mechanism of the Ageing of Duralumin," says that when it is cooled from 500° C. in a furnace, globules of $CuAl_2$ large enough to be seen easily with a high power Microscope, are formed. In the same sample, however, some globules are so small as to be hardly distinguishable, and others too small to be resolved are suggested by the non-uniformity of the surface appearance of the section. When it is considered that the smallest globule of $CuAl_2$ resolvable with a high power Microscope contains about 2,000,000,000 molecules, it is evident that with rapid cooling sub-microscopic particles of $CuAl_2$ must be present in large numbers; in fact, after quenching, the average size of a particle must be submicroscopic. The whole phenomenon of ageing must, therefore, involve changes which cannot be studied directly with a Microscope.

The same author has devoted a great amount of time to the study of grain sizes and their measurement in metals. He has contributed several papers to the Faraday and other Societies in this country. Much valuable information is to be found in the work done by Dr. Zay Jeffries.

Preparation of Specimens and Etching.—In the preparation of specimens for micro-examination great skill and ingenuity have been displayed by numerous investigators from the time of Sorby onwards.

When it is considered that a maximum magnification has now been reached of about 8,000, the difficulties to be overcome will be readily recognised. Supposing the surface of one side of a cube, say one twenty-fifth of an inch square, to be under examination, this has meant that the area under observation has been multiplied or magnified to a surface of say 30 ft. square, or about 900 square feet. It will be seen how the slightest scratch or groove, imperfect polishing, bad etching, or other defect will at once interfere with the desired results being obtained.

In this connection I should like also to call attention to an interesting Paper read by Sir G. T. Beilby, F.R.S., before the Royal Society in February, 1914, entitled "Transparence or Translucence of the Surface Film produced in Polishing Metals." Some beautiful Photomicrographs are there shown, photographed by a 3 mm. Oil immersion Lens of 1.4 N.A. The thickness of the films covering the slight Pits on a Copper surface was stated by Sir George to be probably of the order of 10 to 20 micro-millimetres ($\frac{1}{2,500,000}$ to $\frac{1}{1,200,000}$ inch).

Although if it was possible to get raw surfaces free from all grooves, scratches, and other blemishes, some structure would be developed, it must be remembered that not even the finest polishing will display structure, therefore etching must be employed.

The etching accomplishes two things: it removes the amorphous layer, and then attacks the various constituents differently. The products of the etching attack usually differ in appearance more than the original constituents.

For high power the etching must be very light, that is, the time of etching must be short. A 5 per cent. solution of picric acid in alcohol gives the best results. The perfect flatness of the polished surface must be retained, and only the lightest possible etching is given. In low power work the etching is fairly strong in order to obtain contrast between the light and dark portions.

As regards the effect of different kinds of etching, I invite attention to Photomicrographs, Figs. 9, 10 and 11. These are from a Gun Tube Steel containing .42 per cent. Carbon, .74 per cent. Manganese, and representing material as forged, that is without further treatment.

Fig. 9 was etched with 5 per cent. Picric Acid in Alcohol.
Fig. 10 was etched with 5 per cent. Nitric Acid in Alcohol.
Fig. 11 was etched with 5 per cent. Solution Meta-Nitro-Benzol-Sulphonic Acid.

The structure shows grains of Ferrite on a ground mass of Pearlite and the Photomicrographs prove that the Structure developed is independent of the particular etching reagent used. The number of etching reagents might be extended on this work with practically the same results in each case. Most Alloy Steels, for example, Manganese Steels, quenched and tempered, Nickel Chromium and other Steels,

require extraordinary care in the etching or otherwise the structure will vary considerably and be misleading. Some alloys, for example Steel containing high percentage of Nickel, are not attacked by any ordinary etching reagent.

All honour to Sorby, the man who led the way in this branch of Science, and started us, who are to-day benefiting in such a remarkable manner from the knowledge he first originated and obtained in this important and complex branch of Science. All honour, too, to the band of willing workers who have accomplished such great progress, and who have surmounted the many difficulties in their path.

SECTION V.—STANDARD MAGNIFICATIONS FOR PHOTOMICROGRAPHS.

The question of the Standardisation of Magnifications for Photomicrographs of Metals and Alloys has been given a certain amount of discussion both in this Country and in America.

Committee E-4 of the American Society for Testing Materials has, in fact, drawn up tentative "Definitions and Rules governing the Preparation of Micrographs of Metals and Alloys," which include Standard Magnifications for general use, and Ferrous and Non-ferrous Metals. I have brought this matter before the British Engineering Standards Association, who are considering the subject. The Institute of Metals in this Country in its "Notes for Authors" also specify certain Standard Magnifications which it is desired Authors should use.

Whilst not wishing in any way to hamper the Research Worker, there are reasons why it seems strongly advisable that for general purposes Standard Magnifications should be adopted for the Photomicrographs. Very little quantitative data is forthcoming from the micro-examination of metals. Where the grain size can be determined, this is often distinctly useful and worth recording. For the most part, however, the Microscopist is dependent on a trained eye, resulting from prolonged experience in the examination of microstructures to aid him in their interpretation. It would seem reasonable, therefore, that the magnifications used should be standardised and as few as possible, in order that comparisons between the structures of different specimens may be facilitated.

I would therefore like strongly to urge that the various Societies interested in Metallography should join in drawing up rules governing the reproduction of photomicrographs, which should be of certain Standard Magnifications and naturally should be reproduced full size.

Surely there is every reason for having an International Standard; at any rate, Great Britain and America could work together. It might well, indeed, be made a matter for Allied consideration, or one for consideration in connection with the movement for the formation of International Unions in which the Conjoint Board of Scientific Societies is interesting itself.

SECTION VI.—CRYSTALLOGRAPHY.

As crystallography is, if not directly then indirectly, related to the work of the microscope, I have asked my friend, Dr. A. E. H. Tutton, F.R.S., the eminent crystallographist, to communicate suggestions to this Symposium by way of a Paper or to the Discussion from his point of view.

During the recent Meeting at Bournemouth of the British Association, Miss Nina Hosali, B.Sc. of the University of London, exhibited interesting Models of Crystals. This worker has most kindly submitted her collection this evening and I am sure they will be found useful.

As explained by Miss Hosali, the object of these models is to illustrate :—

(*a*) The forms possible to crystals.
(*b*) The different kinds of symmetry possessed by these forms.
(*c*) How the forms are referred to crystallographic axes.

Each model illustrates one of the thirty-two classes of symmetry, and represents several crystal forms correctly orientated with regard to crystallographic axes, the latter being shown by black threads. A model consists in the first place of a glass envelope whose shape is hat of some simple crystal form, and within this envelope two or three other forms are represented by means of coloured silk threads stretched over frameworks of thin copper wire. By this means it is easy to make the forms intersect if necessary, and they are readily distinguished from one another by the use of differently coloured threads.

The symmetry elements of the class represented by any model are shown as follows :—

(*a*) The traces of the Planes of Symmetry on the Glass envelope are shown by steel wires.

(*b*) Axes of Symmetry are shown by white threads.

The set of 24 models exhibited represents 21 out of the 32 classes and over 70 different forms. In many cases different varieties of the forms may be produced by rotating or inverting the models, or by reflecting them in a mirror, and when these modifications are taken account of, the number of the forms shown is brought up to about 140.

It may be interesting to add that there has been recently developed and described by the Research Committee of the American Society of Mechanical Engineers an instrument called the Microcharacter (from the Greek—to engrave or scratch on a small scale). This instrument determines that characteristic of a crystal which is the combination of three of the five fundamental conceptions of hardness, namely, the combined effect of cutting, scratch, and penetration hardness. It can be employed for determining the hardness of the micro-constituents of steel and should be very useful to the Metallographist. This Apparatus should be very useful to the Metallographer, as the

point used is practically sharp under a magnification of no less than 2000 diameters. By this method these combined characteristics can be obtained for any individual crystal, a point of great importance.

SECTION VII.—THE ULTRAMICROSCOPE.

Much study has been given to the Ultramicroscope, which was introduced about the year 1905 by Siedentopf and Zsigmondy.

In an article which appeared in "The Scientific American," October 2nd, 1915, it was stated that the limits of microscopic observation with direct illumination is about $\frac{1}{4,000}$ mm. and with oblique illumination by means of violet rays and with the aid of monobromated naphthalene immersion $\frac{12}{100,000}$ mm. The observation of particles below this may be termed ultramicroscopic. According to Siedentopf, particles may be perceived which have a diameter of about $\frac{4}{1,000,000}$ to $\frac{6}{1,000,000}$ mm. These are magnitudes which approach very closely to molecular dimensions of complicated compounds, in some cases even attain them.

According to O. E. Meyer, the molecule of Hydrogen has a diameter of $\frac{1}{10,000,000}$ mm., while according to Jaeger, the molecule of (*a*) ethyl-alcohol has a diameter of $\frac{5}{10,000,000}$ mm.; (*b*) chloroform has a diameter of $\frac{8}{10,000,000}$ mm. According to Lobry de Bruyn, the molecule of starch has a diameter of $\frac{5}{1,000,000}$ mm. Consequently the molecule of starch must be within the reach of ultramicroscopic perception.

The investigator has therefore before him, subject to increased intensity of light and dark field, the possibility of seeing molecules which seemed beyond reach of human sight, and the hope of following the play of their attractive and repellant forces. The brightness of ultramicroscopic particles begins to decline with the 6th power of the diameter.

If it should prove possible to obtain this deeper insight into the form and structure of matter, a positive service will be done to philosophy permitting of the observation of particles which were formerly far below the limits of ordinary microscopic observation. If the methods which it renders possible can be extended and applied to Metallurgy, then the Metallurgist will doubtless be possessed of still further means to enable him to advance further our knowledge of the structure of metals and their alloys.

SECTION VIII.—CONCLUSION.

I must now bring these remarks to a close. The subject is a fascinating one, and it has been a labour of love to trace the History of the Microscope and its great development into the wonderful Scientific Instrument of to-day, capable of resolving even over 100,000 lines per inch.

If Sorby could have been with us this evening it would be a special satisfaction to him to see the child of his brain grown to the giant it now is, I mean in the application of the Microscope to the examination of Metals and their Alloys. In a separate communication entitled "The Great Work of Sorby, of Sheffield," I have dealt briefly with his Researches in this field.

In addition to this present Address, I am contributing to the Symposium a Paper on the Faraday Society and its Work; also jointly with Mr. T. G. Elliot, F.I.C., a Paper on "Photomicrographs of Steel and Iron Sections at High Magnification," as well as a Bibliography from 1665 down to the present time, which although not claimed to be complete may be found useful to those interested.

I trust that in each of these contributions will be found some information that may be of interest and give encouragement to pursue our Researches in this valuable field of Scientific Investigation.

SECTION IX.—BIBLIOGRAPHY OF THE CHIEF LITERATURE RELATING TO MICROGRAPHY.

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1668	Account of Divinis' Compound Microscope		Phil. Transactions, No. 42	England	Paper
1718	Descriptions et Usages de plusieurs Nouveaux Microscopes, tant Simples que Composez	L. Joblot		France	Paper
1798	Essays on the Microscope (Bibliography)	G. Adams		England	Paper
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Mar. 1854	On the Construction of the Compound Achromatic Microscope	C. Brooke	Royal Inst., Great Britain	England	Paper
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Date.	Title.	Author.	Publication.	Country.	Description.
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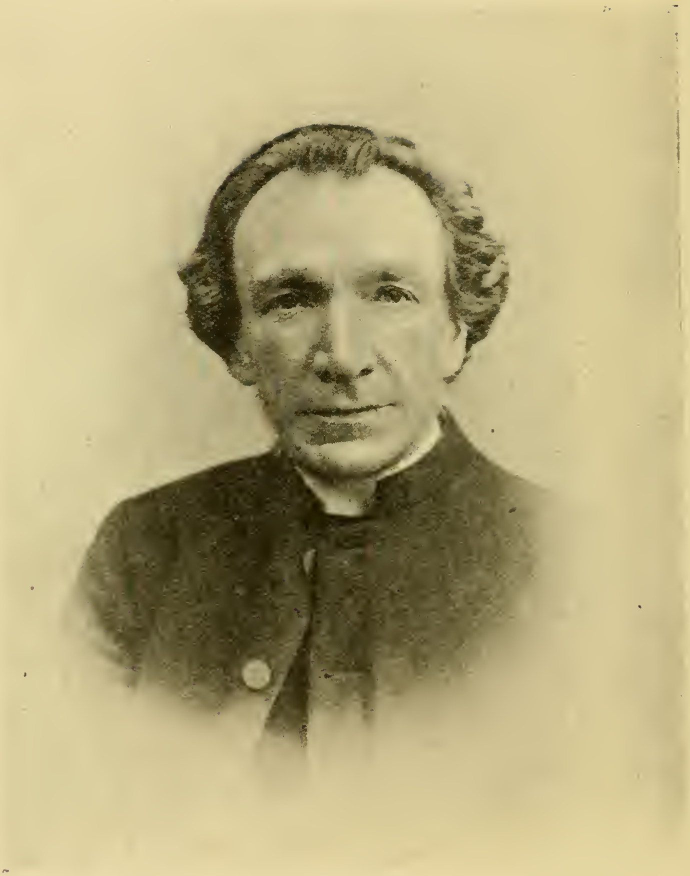
1919	The Solidification of Metals	Dr. C. H. Desch	Inst. of Metals	England	Report

Dr. H. C. SORBY, F.R.S., of Sheffield.

President of the Royal Microscopical Society in 1875-7.

FIGURE I.



DR. W. H. DALLINGER, F.R.S.

FIGURE 2.


ZACHARIAS IANSEN,
ſive Ioannides primus Conſpiciliorum inventor.

FIGURE 3.

FIGURE 4.

MICROGRAPHIA:

OR SOME

Physiological Descriptions

OF

MINUTE BODIES

MADE BY

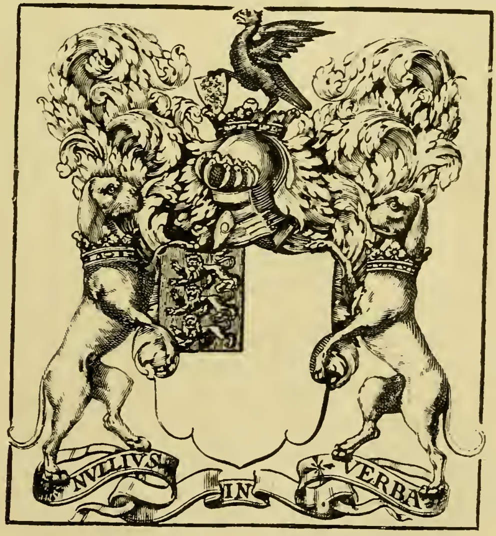
MAGNIFYING GLASSES.

WITH

OBSERVATIONS and INQUIRIES thereupon.

By *R. HOOKE*, Fellow of the ROYAL SOCIETY.

Non possis oculo quantum contendere Linceus,
Non tamen idcirco contemnas Lippus inungi. Horat. Ep. lib. 1.



LONDON, Printed by *Jo. Martyn*, and *Ja. Allestry*, Printers to the ROYAL SOCIETY, and are to be sold at their Shop at the *Bell* in S. *Paul's* Church-yard. M DC LX V.

Rob: Hooke :

FIGURE 5.—Representing the front page of Hooke's "Micrographia," published in 1665.

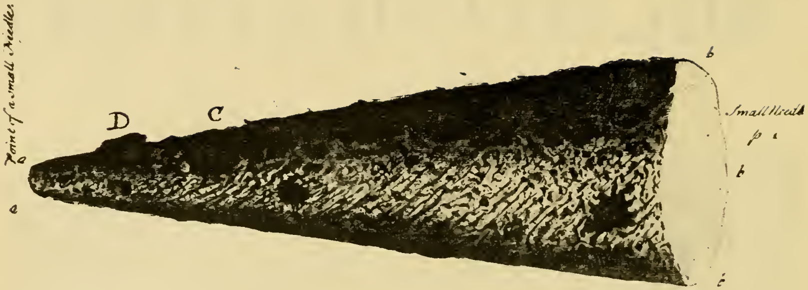


FIGURE 6.

Point of a needle, magnified.
Reproduced from a Drawing made by Hooke in the year 1665.

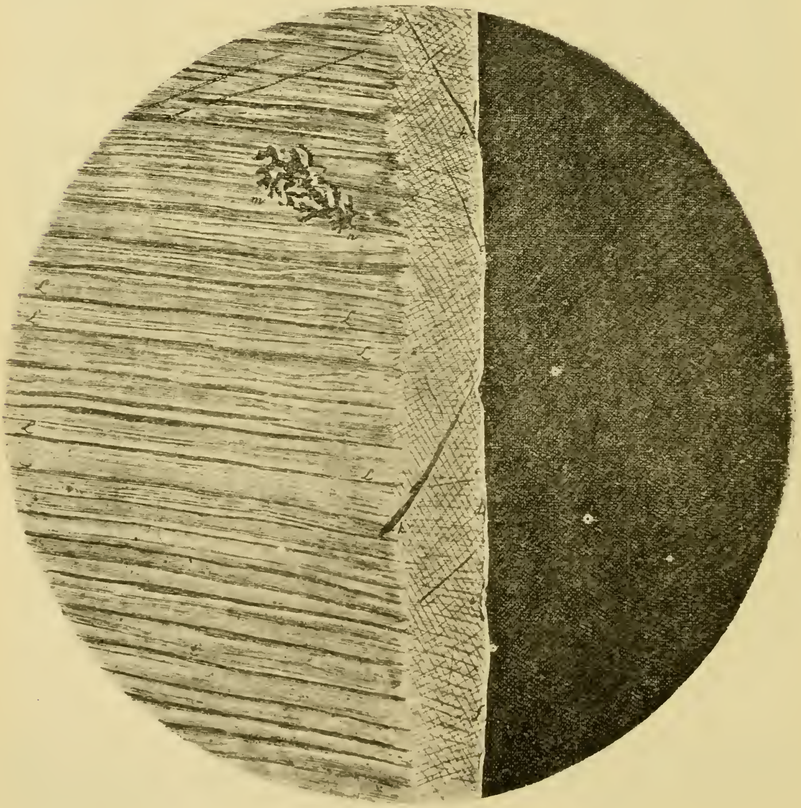
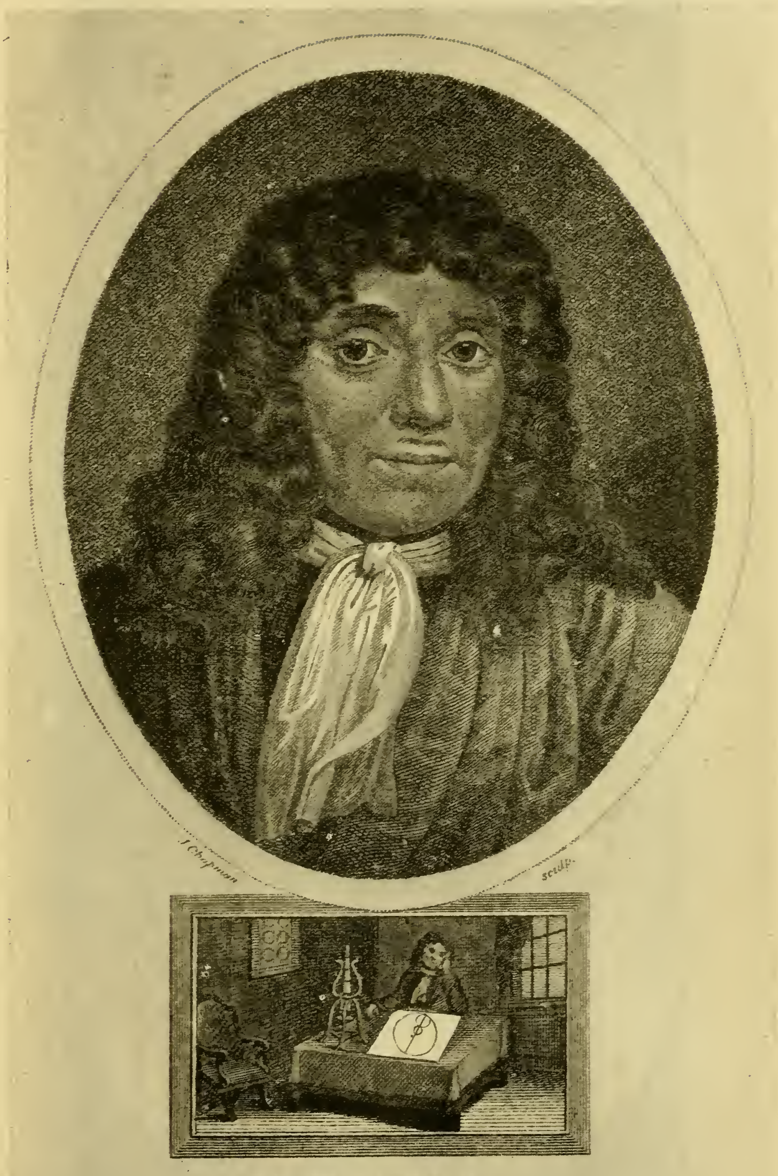


FIGURE 7.

Edge of a razor, magnified.
Reproduced from a Drawing made by Hooke in the year 1665.

These Figures are about three-fifths size of Hooke's enlargement.



LEEUWENHOEK.

FIGURE 8.

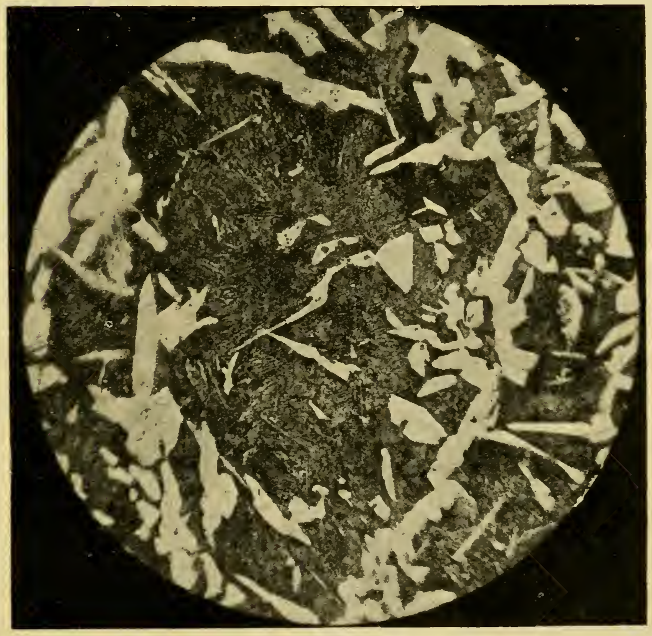
Magnification 100.
Etched with 5% Picric Acid in Alcohol.

Magnification 100.
Etched with 5% Nitric Acid in Alcohol.
FIGURES 9 AND 10.
Photomicrographs showing that the Structure of a Gun Tube Steel is independent of the etching reagent.

Analysis: C. .42, Mn. .74%.

Treatment: As Forged.

The Structure shows grains of Ferrite on a ground mass of Pearlite.

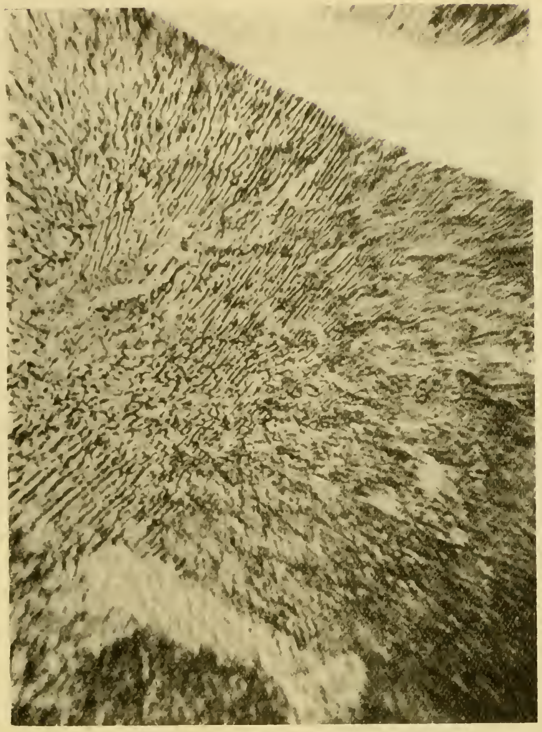


Magnification 100.

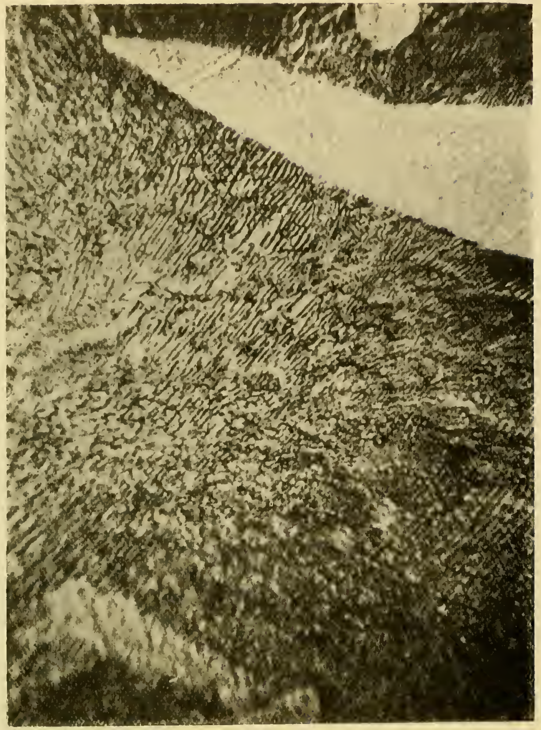
Etched with 5% Solution Meta-Nitro-Benzol-Sulphonic Acid.

FIGURE 11.

Photomicrographs showing that the Structure of a Gun Tube Steel is independent of the etching reagent



Watson 2 mm. British-made Apochromat.
Magnification 1,500.
FIGURE 12.



Foreign 2 mm. Apochromat.
Magnification 1,500.
FIGURE 13.

THE PRESENT POSITION AND THE FUTURE OF THE MICROSCOPE—A GENERAL SURVEY.

By J. E. Barnard,

President of the Royal Microscopical Society.

Mr. J. E. Barnard, President of the Royal Microscopical Society, then delivered an address, of which the following is a condensed report, in which he indicated future lines of development in microscope design and in microscopy.

On behalf of the Royal Microscopical Society, I trust I may be allowed to convey to Sir Robert Hadfield the expression of my great appreciation of the efforts he has made, resulting in the holding of this Symposium. The subject is one that is in need of discussion; but, had it not been for Sir Robert's scientific insight and energy, it is unquestionable that the meeting would never have taken place. As the time that is allotted to me is of necessity short, it will be impossible to give anything like a full survey of the subject of microscopy. I shall, therefore, be compelled to limit myself to such points as appear to me to be of interest, although I admit that I am not always selecting the ones of greatest importance.

An examination of the programme of this Symposium might lead to the conclusion that the subject of metallography was the most important branch of microscopical research. In point of fact this is not so. Although the importance of the subject is admitted, yet the amount of attention given to it is not anything like so great as that devoted to biological researches. It is therefore probably quite true that ninety per cent. of the microscopes in use at the present time, whether in this or any other country, are in the hands of those who are working at biological subjects. Even of this class, the science of medicine will absorb the greater portion; and it is therefore unfortunate that the medical side of the subject is treated so lightly—at least, if we may judge from the programme. It is, I am afraid, only in accordance with the accustomed attitude in medical circles for little interest to be taken in pure microscopy, although in diagnostic work the importance of the microscope has never assumed a larger place.

In view of the paucity of contributions on the biological side, I shall, therefore, direct more attention to this than I should otherwise have done, and the few remarks I make will be more particularly in relation to the microscope as used for biological research.

A consideration of the microscope resolves itself of necessity into two parts, the mechanical and the optical. From the mechanical standpoint there are two designs in general use—those referred to as the Continental and the English form of microscope. In the Continental type it has usually been customary to have what is known as the horseshoe foot, mainly, I imagine, because of its ease of construction by mechanical engineering methods; whereas the English design of microscope, which has hitherto been mainly made by hand, is of a more steady type, and the points of support are so distributed as to give more stability to the instrument in any position.

The essential parts of the instruments are a coarse adjustment, to give the body tube a quick motion in the direction of the optic axis, and a fine adjustment, which gives it a much slower motion in the same direction. The tube is adjustable in length, to enable correction to be made for varying thicknesses of cover glass, although a large number of workers appear to regard it as a ready method of obtaining greater or less magnification, with disastrous effects on the resulting image.

There is only one fixed part of a microscope which is used for biological purposes, and that is the stage. But metallographers require that the stage shall also be adjustable in the direction of the optic axis. The body tube itself should be made so that it can be closed to a length of 140 millimetres, including any objective changing device that may be on the nose-piece; and it should be possible to lengthen it to at least 200 millimetres or 250 millimetres if long-tube objectives are used.

All these adjustments are in the direction of the optic axis of the instrument. Two others are usually provided, which are at right angles to this direction—that is, a mechanical stage for actuating the object, and in certain of the best class instruments an arrangement for centering the sub-stage condenser to the axis of the objective. While there are many points which might be raised on the mechanical side, there are only one or two that I have time to mention. The main points about most microscopes appears to be that they are unstable. I have a considerable number in my own possession, but I do not think I have one, even now, which, if I centre an object on the stage with the instrument in a vertical position, still maintains its centration accurately if the instrument is put into the horizontal. The probability is, therefore, that there are few microscopes made at the present time that exactly fulfil the conditions necessary for high-class photomicrographic work, or for observational microscopic work of an exacting order. I trust, however, that an instrument exhibited at this Symposium will embody the necessary improvements to rectify this matter.

Some misapprehension appears to me to exist also as to the relative purpose of the coarse and the fine adjustments. The coarse adjustment should be sufficiently well made, and if the user is sufficiently expert, to enable him to bring into view any object, whether it is being observed with a low or a high power objective. The fine adjustment is then used for accurate focussing and for getting a conception of the object in depth. In biological work, at any rate, this is very rarely the state of affairs as carried out. In using

an oil immersion objective, for instance, a common method is to immerse the objective and then lower it so that it all but touches the top surface of the cover glass. The objective is then raised by means of the fine adjustment until the object comes into view. While this may act fairly well with very thin cover glasses, it is a haphazard method when cover glasses of varying thicknesses are used. It should be realised that when microscope users are sufficiently educated, they will be able to tell how far they are from the actual image by the appearance of the light in the field of view, that is, if the object is illuminated with reasonable accuracy.

Mechanical stages also appear to me to need some consideration. The stages which will on actuation cause no shift of the object other than in the direction intended, or any alteration of focus, are rare. Further, those in which the screws project over the side for a considerable distance with the result that any slight jar or knock causes them to be displaced, and, it may be, actually bent, are objectionable when used under laboratory conditions.

There is, I think, much to be said for the type of stage which has either co-axial milled heads on a vertical axis, or, if inconvenient to make, milled heads which are on separate axes. This method of construction, I think, of necessity results in a much stiffer and more stable stage. There is, in fact, a general lack of stability going through nearly all parts of a microscope. But it is significant that, even so long ago as the beginning of last century, the instrument as then designed had much greater attention paid to this point. The microscope, an illustration of which I show on the screen, is to my mind an embodiment of a principle that should receive attention. So soon as English makers are in a position to consider the production of an instrument of a special type, it is my intention to have one made. In this the general principle is that all the optical parts are carried on a bar which is, in effect, an optical bench, and that this is strutted in such a way as to give stiffness to the instrument as a whole. The only effort that I am aware of that has been made in this direction is in the microscope designed by Dr. Rosenhain, particluarly for metallography, but which is adaptable for ordinary work. This instrument, to my mind, is such an improvement on any other type of stand that I am at a loss to understand why metallographers have not more generally taken it up. It might appear that I am exaggerating the importance of stability in the stand. But it should be realised that any want of centration in the optical parts, or want of alignment in the optic axes of these parts, results in more serious deterioration of the resulting microscopic image than any other single factor. The optical parts of a microscope are the objective, for obtaining the primary magnified image of the object; the ocular, for further enlarging that image and transmitting it to the eye; and the sub-stage condenser, for illuminating the object with a larger or smaller cone of light. The limitations of time will prevent me from doing more than refer very briefly to some properties of the optical parts.

It is generally assumed that magnification is the primary function of an objective. But in point of fact the main point is not magnification but resolution. By resolution is meant the power the

objective has of separating and forming correct images of fine detail. That known as the Abbe Diffraction Theory, is the theory on which modern optical calculations are based, and it is safe to say that it was never more fully accepted and never rested on a surer basis than at the present time. There has been much discussion in this country of that theory, and probably a good deal of misconception has arisen from its inapt designation; for the term "Diffraction Theory" is perhaps somewhat unfortunate. I cannot do better than quote the late Lord Rayleigh in reference to this matter. He said: "The special theory initiated by Professor Abbe is usually called the Diffraction Theory, a nomenclature against which it is necessary to protest. Whatever may be the view taken, any theory of resolving power of optical instruments must be a diffraction theory in a certain sense, so that the name is not distinctive. Diffraction is more naturally regarded as the obstacle to fine definition, and not, as with some exponents of Professor Abbe's theory, the machinery by which good definition is brought about."

This very clearly and accurately sums up the position. The Abbe theory tells us that there are two main factors determining resolution: that is, the numerical aperture of the objective used, and the wave-length of the light. Numerical aperture is determined for us by the optician, and it is well known that, with an oil-immersion objective, a numerical aperture of 1.4 is at the present time the practical limit. Metallographers are in a somewhat stronger position, as a mono-bromide of naphthaline immersion objective was, and presumably still is, made by Zeiss, which had a numerical aperture of 1.6. This represents the absolute limit at the present time, and there is no indication that numerical aperture will be increased in this sense by present methods.

The other factor governing resolution is the wave-length of light, and in this connection it must be borne in mind that to resolve a regularly marked structure, the distance between the markings must be more than half a wave-length. Under ordinary conditions of illumination we cannot go very far in the direction of increased resolution unless we have resort to an illuminant such as a mercury vapour lamp, which is rich in blue and violet radiations. There is much room for investigation in this direction, as the ideal illuminant for microscopic work has yet to be found. But I do not know of any one that approaches so nearly to it as the one I have mentioned—the mercury vapour lamp. It suffers only from one disadvantage that I can see, and that is that the differentiation due to staining is not so clearly brought out as when ordinary light is used. But as staining is itself an artificial process, and is simply done to differentiate structures, it only means a certain amount of education to enable us to appreciate the differences, even under the light from this lamp. The only stains which it does not show quite well, or, rather, in which the colour-tint is altered, are those in which red predominates. Any other colour is shown perfectly and in reasonable gradation. The advantages of this illuminant are that it is even and uniform. It has a fairly large area, and can be used therefore for any class of work. Its intensity can be varied within considerable limits by having a resistance in series, so that the current density is altered to suit the particular

work under observation. Further, it is possible, by interposing neutral screens, to vary the light intensity if the electrical method is inconvenient. Owing to its possessing practically no red radiations, its mean wave-length is shorter, and by using suitable screens light which is truly monochromatic, green, blue or violet, can be obtained at will. These lamps are made both in glass and quartz, but the quartz ones are preferable, because they admit of the use of heavier current, with greater luminosity; and further, they have a much longer life. I have exhibited two of these lamps, because I regard them as far in advance of any other form of light available to the microscopist at the present time, whether he is a biologist or a metallographer.

The whole subject of illumination, so far as the illuminant is concerned, needs investigation also, because there is, I think, little doubt that a modification in the intensity of the illumination of any particular object enables us to use a larger light cone than we could do under ordinary circumstances. That is, variation of the intensity is an alternative to the use of the iris diaphragm in the sub-stage of the microscope. But it is in the direction of using invisible radiations in the ultra-violet, or, it may be, radiations which are still shorter than the ultra-violet, that developments in microscopic work are, in my opinion, likely to occur.

There are two other points, which I can only refer to, but which, I trust, may be dealt with more fully in the succeeding papers. One is that, while the resolution limits are so inflexible, that does not by any means apply to mere visibility. By illuminating small particles by means of an annular cone of rays, that is, what is ordinarily known as dark ground illumination, or by illuminating them at right angles to the optic axis of the microscope—what is known as the ultra-microscopic method—particles of a very much smaller order of size can be made visible. But we cannot tell anything about their form, nor can we accurately tell their size. We are only conscious of their mere existence.

Another point to remember is that magnification is definitely limited to something like 750 diameters with microscopes under ordinary conditions, if we want to get the best optical effect. We may, as a matter of convenience, have still higher magnifications, because it is not given to everybody to appreciate fine detail unless an image is somewhat enlarged. But it must be appreciated that any increase beyond 750 or 800 diameters does not result in us seeing anything more. It simply allows us to see the object on a somewhat larger scale. We may therefore summarise as follows:—An object which is much smaller in size than the resolution limit can be rendered visible, providing the light with which it is illuminated is of sufficient intensity, and it is sufficiently different in refractivity from the medium in which it lies. To resolve a series of equi-distant points or lines in an object, their distance apart must exceed half a wave-length of light in the medium in which the object is immersed. Johnstone Stoney has shown that a pair of lines or objects can be separated when their distance apart is rather smaller than the resolution limit required for a number of points or lines in a row. But it should be borne in mind even here that the resolution limits apply if a definite standard of definition is required. An isolated object, or pair of objects, are not so well

defined if they exceed the resolution limits as laid down for recurring structures. It cannot be too fully appreciated that illumination is the keynote of all sound microscopic work, and this applies whether the illumination is by means of visible radiation under ordinary conditions of work, or whether it is in experimental work in which the use of invisible radiations are concerned.

There is much room for research in this direction, and it is to be hoped that this is one of the points which will be seriously taken up. Apart from any question of research, the education of the user is perhaps of vital importance. It is little use for opticians to make great efforts to turn out a satisfactory instrument if the user is incapable of taking advantage of the quality of the optical or other parts. I trust, therefore, that this Symposium will give an impetus in this direction, and that it will help microscope users to realise how much remains to be done.

ADDRESS BY SIR HERBERT JACKSON, K.B.E., F.R.S.

At this stage **Sir Herbert Jackson** delivered an Address, which is printed on page 213 of this Report, owing to an unavoidable delay in preparing it for publication.

Professor F. J. Cheshire, C.B.E., President of the Optical Society, read a paper on "The Mechanical Design of Microscopes."

THE MECHANICAL DESIGN OF MICROSCOPES.

By Professor F. J. Cheshire, C.B.E.,
President of the Optical Society.

The optical industry in this country, as the result of war experience, has been specially recognised by the Government as a key industry, which, in the national interests, therefore, must be encouraged and preserved.

Now the microscope, whether considered from the point of view of the great and increasing demand which it makes upon the highest technical knowledge and skill of the optician and the mechanician, the importance of the work which it is called upon to do, or the great demand for it, stands forth as the most important of all optical instruments. It is thus the keystone of the arch of a key industry. The optical industries of any country which is producing microscopes for which there is a world's demand must be in a healthy and thriving condition. Conversely, any country which fails to produce a microscope to meet the world's demands is very unlikely to have the reputation for producing, on a commercial scale at at any rate, important optical instruments of any kind. The production of the microscope may therefore be accepted as the touchstone of national success in optical activities generally. The importance of this point must be insisted upon—when England can produce microscopes in large numbers for the world's markets, the success of her industries will be assured. Until it does so, that success cannot be accepted as assured.

The development of a mechanical invention which is ultimately required to meet a big demand, usually follows upon well defined lines. At the beginning, when the demand is small, the labour of highly skilled craftsmen is necessary and sufficient for its production, but later, when the demand has increased, it is found that for efficient production the skilled craftsman is no longer sufficient, but special machinery must be put down to replace him. In other words, artistic production is followed by machine production.

As an illustration of production in the artistic period, I cannot do better than tell you a story that was told to me some years ago by the late Dr. Czapski. Dr. Czapski upon one occasion visited Hartnack, the famous maker of microscope water-immersion objectives. He found him sitting on a stool in front of a window, busily engaged assembling the systems of his objectives with the aid of a microscope and a test-object. On the table by his side were a number of grooved sticks, each filled with a number of a particular lens wanted in a certain objective combination. Hartnack, with his great knowledge and skill, was able to look at a critical object and decide from its appearance what lens in a given combination was likely to be responsible for the observed defects. He would then try another and slightly different one in its place. In this way he would try combination after combination, until a satisfactory result was obtained. Occasionally by a fortuitous accident he would obtain an objective much superior in its performance to the general run. These were carefully put on one side, and although Hartnack charged a uniform price for all his objectives, he was very careful to allow none but serious workers to obtain possession of the best quality lenses. Now Abbe realised that this method of production, making such great demands upon unique knowledge and skill, could not possibly meet the growing world's demand for microscope objectives, and therefore that the highly skilled, technical artist must be dispensed with and replaced by mechanical processes capable of producing to a high order of accuracy predetermined elements. This was done, and that success which is now a matter of history, achieved. Some time ago I was discussing this subject with Sir Howard Grubb, and he gave me a remarkable instance from his own experience. He told me that before the war he employed a skilled man to rough out certain lenses by hand at the rate of about a dozen per week. When the war broke out it was realised that something must be done to expedite production, and Sir Howard Grubb invented a special machine, attended by a girl, to perform the necessary operation. The result was that the girl and the machine turned out more than a thousand of these lenses per week.

It follows from what has been said that the microscope must meet not only the demands of the user, it must meet also those of the manufacturer. I suggest, therefore, that a well designed commercial microscope may be defined as one that can be made both accurately and cheaply, and that secures in its use "the greatest happiness of the greatest number." First, it must be a commercial article, one made in great numbers to compete in the markets of the world. Secondly, it must be made accurately and cheaply. These requirements necessitate on the part of the manufacturer specialisation, standardisation, production by repetition machinery

of the most modern types, attended by unskilled labour; the whole of these activities being directed by the highest technical knowledge and skill. Thirdly, a well designed microscope must confer the greatest happiness upon the greatest number of its users. In other words, it must meet to the fullest possible extent, the needs and demands of its users. But these demands are constantly changing and increasing. Demands resulting from war experience, for example, are already of a formidable nature, and are certain to become greater. One fundamental difficulty in design must be noted. A good design having been evolved to meet existing requirements, there is always a strong temptation to meet new requirements by a modification of the old design. In any particular case this may or may not be satisfactory, but one is often inclined to wonder whether this subservience to tradition has not resulted in the perpetuation of designs which, however good they may have been at one time, are now ill-adapted to meet more exacting requirements. A thorough overhaul of the design of the microscope by thoroughly skilled mechanicians, without reference to old and traditional designs, might lead to startling and valuable results. This is a point of great importance to the trade. So long as a manufacturer confines himself to the production of well-known designs, he must of necessity meet with keen competition. Should he, however, be successful in introducing new and valuable features, his chance of success is very greatly increased. This danger of too close an observance of traditional designs is unfortunately enhanced by mass production, because when a manufacturer has laid down expensive plant to produce a given design, it often pays him—or he thinks it does—to buy up patents for improvements upon it, and throw them into the waste-paper basket.

Again, in the elaboration of a standard design we all agree that the faddist must not be considered—the greatest happiness of the greatest number must be sought for. Here, again, the matter is not so easy in practice. We are now told that the bullet which eventually brought down the Zeppelin so ignominiously was, in the first case, refused as the suggestion of a crank. Many valuable suggestions for the improvement of the microscope must also have been turned down for the same reason in the past.

Time, unfortunately, does not permit of any consideration or criticism of the design of the details of the microscope, but there is one matter of some importance to which I should like to draw your attention. In the early days of the microscope the illuminating apparatus was of the simplest kind, generally nothing more than the sky or a common lamp, the light from which was thrown upon the object by a simple mirror. Modern work, however, demands a well-corrected condenser of large aperture—or it may be a dark-ground illuminator—working in conjunction with a small and intense light source accurately adjusted in the axis of the complete illuminating and observing systems. Now this adjustment of the light source is tiresome in the case of an expert, and difficult in the case of a tyro, and, when made, a touch of the mirror, or a slight accidental displacement of the microscope or the lamp, necessitates the work being done again. This difficulty could be largely removed by the simple expedient of resting the microscope and the lamp on geometrical bearings of the three-radiating groove type. In the

case of the microscope these grooves could be cut in the foot of the instrument to rest upon and engage with three studs on the table. This arrangement would be simple and cheap, and would have the further advantage that it would not in any way interfere with the use of the microscope in the usual way—the grooves when not in use would not scratch the table top. In this simple way the placing of the lamp and the microscope in a fixed position with respect to one another, would be secured. It would then only be necessary to fix the mirror, as has been suggested by Mr. J. E. Barnard, and the microscopist would, in a few seconds, be able to ensure that a beam of light was being thrown accurately along the axis of his microscope, a necessary condition, for example, of the efficient use of the dark ground illuminator in bacteriological work.

I have not been able to say much, ladies and gentlemen: the time has been too short, but I hope that I have been able to say something which will assist you to realise the national and far-reaching importance of the subject with which we are concerned at this Symposium to-day.

Mr. F. Martin Duncan, President of the Photomicrographic Society, then gave a résumé of his paper, "Some Notes on the History and Design of Photomicrographic Apparatus."

SOME NOTES ON THE HISTORY AND DESIGN OF PHOTOMICROGRAPHIC APPARATUS.

By F. Martin Duncan, F.R.M.S., F.R.P.S., F.Z.S.
President of the Photomicrographic Society.

No survey of the present position of microscopy would be complete without a reference to the very important part which photomicrography plays as a means of accurately recording the various objects which are submitted to microscopic examination. To the investigator in bacteriology, biology, and metallography, a photomicrographic apparatus is to-day an essential part of his microscopic outfit, and therefore the consideration of the design of such apparatus has become a matter of prime importance.

Scientific workers were quick to realise the value of photography as a means of obtaining an unbiased graphic record of their observations, and it was only the limitations and technical difficulties of the early processes that prevented its wider use. From the time of its first discovery there have been microscopists who have employed photography in preference to the pencil. Thus in 1845 Doune and Foucault illustrated their "Atlas of Microscopic Anatomy" by etchings from photomicrographs taken on Daguerreotype plates, while as early as 1835 Fox-Talbot had obtained images of objects in the solar microscope by means of his recently discovered process. It would be out of place here to enter into a description of the early pioneers of photography, intensely interesting though the subject be, but in passing one cannot help feeling proud of the fact that the discovery of photography was due to British and French scientists alone, and that the first to apply it successfully to the recording of microscopic objects were Fox-Talbot in England, Daguerre in France, and Draper in America. And since those first days of the history of photomicrography, it has been in France, in Great Britain, and in America that the greatest experts, the most notable advances and inventions, and the most perfect apparatus for photomicrography have been produced.*

Naturally the apparatus used in the early stages of the application of photography to microscopy was of a somewhat crude character. The earliest cameras were little more than light-tight boxes, while many of the pioneers dispensed with any form of camera at all, the

* For a short account and early bibliography see an article entitled "Chapters in Photomicrography," which I contributed to the *British Journal Photographic Almanac* for 1903, pp. 691-725.

eye-piece end of the microscope being inserted through a circular hole in the wall of the dark-room, and the Daguerreotype plate, or the wet collodion plate placed upon a board in the dark-room, on which the image formed by the microscope had previously been focussed. Considerable difficulties had to be overcome in obtaining the correct adjustment that would yield a sharp, crisp image, owing to the, at that time, imperfect corrections of microscope objectives; but gradually from such crude beginnings the practice of photomicrography has attained to its present high standard of technique. That the rapid improvement and high standard of perfection to which microscope objectives, eye-pieces, and substage condensers have reached are largely due to the investigations and labours of Abbe, Schott, and Zeiss, all microscopists will readily admit; but that is about all, though admittedly it is a very important contribution, that can honestly be claimed by Germany as her share towards the perfection of photomicrography.

I know that opinions are very sharply divided on the subject of the microscope stand as made by British and German manufacturers, and I feel that much of the criticism that has been levelled at the British manufacturers is grossly unfair and inaccurate, because in nine cases out of ten the would-be critic is already prejudiced in favour of the German, has not a thorough technical knowledge or experience, and frequently has never used a really first-class British stand. I am quite ready to admit that the British maker has turned out some very poor models, but so has the German; but because the Britisher has produced some cheap models of poor quality, surely that is no reason for damning at sight everything he produces. You are not going to encourage home enterprise or industry by such methods. I have now used the microscope practically daily for over thirty years in my biological investigations, and during that time models by all the leading British and Continental manufacturers have passed through my hands, and have been, I hope and believe, honestly, critically, and impartially tested. Out of that long experience I am bound to say that for comfort in working, rigidity, and perfection in design and workmanship, I have yet to see the German or Continental model that will touch the very best productions of our leading British manufacturers. In no branch of microscopy is the superiority of the first-class British microscope stand more readily demonstrated and realised than in critical high-power photomicrography, for to produce the best results, rigidity, whether in the vertical or horizontal position of the microscope body, and ease of manipulation of the mechanism of the substage and the top or object stage are factors of vital importance—factors which are not present in the horseshoe foot, or the finicky studs and knobs provided for the adjustment of substage and substage-condenser, and mechanical stage, in the German models. Even the large Zeiss model specially designed by that firm for photomicrography, though of good workmanship, suffers from these inherent defects of the Continental model, its substage mechanism being very cramped, and the mechanical stage provided with wretchedly small pinion heads.

The microscope stand intended for critical photomicrography and original research should have a solidly cast broad tripod foot, such as is present in the large research model of Swift, the R.M.S. model

of Baker, or the Royal and Van Heurck models of Watson. The focussing of the substage condenser should be by a stout pinion of such a length that the hand does not have to grope for it beneath the stage, and should be provided with a good milled head. Fairly stout pinions and milled heads should also be provided for controlling the vertical and transverse movements of the mechanical stage, while the body-tube should be of large diameter to admit the use of low-power objectives required when photographing comparatively large fields.

Between the years 1889 and 1899, Messrs. Swift and Messrs. Baker produced two very fine photomicrographic cameras that might well to-day rank as standard models for critical high-power work. That made by Messrs. Swift incorporated designs suggested by Mr. Andrew Pringle, and that by Messrs. Baker the ideas of the late Mr. C. Lees Curties—both experienced microscopists and photomicrographers. The essential features of each outfit are very similar, and consist of (1) a long solid baseboard forming a rigid foundation on which the whole apparatus is built; (2) a substantial square-bellows camera travelling on a wide base and capable of considerable extension; and (3) a substantial turntable for the support of the microscope condensers and illuminant. On account of the wide, solid base on which the square-bellows camera travelled, the camera could be extended to its fullest degree and used in that position without fear of vibration during long exposures. With such apparatus the formidable task of obtaining sharp negatives at a magnification of upward of two thousand diameters linear, could be accomplished with certainty, and, given the necessary technical knowledge, celerity and ease. It is no light task to be called upon to produce large numbers of photomicrographic negatives at such high magnifications, when the work has to be carried out in a house past which heavy street traffic is continually travelling, yet such formed a part of my duties during the terrible years of the war, and was made possible only by the use of apparatus of the design I have just described. Before the work was placed in my hands, attempts had been made to carry it out with photomicrographic apparatus mounted on iron rods, the typical German design; and therefore, of course, supposed to be vastly superior to anything British. The failure was due to no want of skill on the part of the users of the apparatus, but to its inherent faulty design, for it is obvious that vibration will be more readily conducted and its amplitude increased along the rods than through a solid base. Both from long pre-war experience and from the result obtained in that part of my war work just described, I feel that I am fully justified in stating that the right design for photomicrographic apparatus intended for critical high-power work is on the lines of the Pringle-Lees Curties models, or the more recent designs of Singer made by Messrs. Watson and Sons, and of Barnard, made by Messrs. Baker.

It frequently is necessary to take photomicrographs with the microscope in the vertical position, and here again to employ a camera clamped to an upright iron rod is asking for trouble, to say the least, yet that is the design dear to the heart of the German manufacturer. Many years ago now, Messrs. Watson and Sons placed on the market a vertical model made to the design of the veteran microscopist, the

late Dr. Van Heurck. The apparatus consists of a vertical box-form camera supported on four stout square legs, between which, and immediately beneath the camera, the microscope is placed. The whole is very rigid, and we all know the magnificent work Dr. Van Heurck and others produced with it. The chief objection, and, when considered on optical grounds, to my mind not a very real one, is that it precludes the employment of extended camera lengths. But ten inches from the eye lens of the eye-piece to the focussing screen of the camera is, I believe, the ideal extension for critical work with modern objectives. In the *Journal of the Royal Microscopical Society* for 1916, pages 258-9, I have figured and described a simple home-made vertical stand to carry microscope and camera, and although there shown as used for stereo-photomicrography, I have since used it successfully for high-power work with the monocular microscope with magnifications up to two thousand diameters.

A vertical apparatus of good, rigid design is of such importance for a great deal of microscopical research work that is being carried out to-day, that it is a matter deserving the immediate and serious consideration of our British manufacturers.

Dr. Charles Singer presented the following paper on "The Earliest Steps in the Invention of the Microscope." The paper was taken as read.

THE EARLIEST STEPS IN THE INVENTION OF THE MICROSCOPE.

By Charles Singer, M.A., M.D.Oxford, F.R.C.P.Lond., F.S.A.

The microscopes and the microscopic work of the classical observers, Leeuwenhoek, Malpighi, Hooke, and Kircher, have been frequently described and figured. These descriptions are readily accessible, and I shall therefore confine myself to the earliest stages in the discovery of the microscope, which is, of course, intimately connected with the invention of the telescope. About these early stages vague statements are often made, but the actual data do not seem to have been put together.

(1) *Euclid* (third century, B.C.), in his *Optics*, considered that light passed in straight lines, and regarded an object seen as formed by a cone with its base at the object and the apex at the eye. The Euclidian origin of this work is disputed by some, who hold that is is by Theon of Alexandria, who lived in the fourth century, A.D., and was perhaps the father of Hypatia. The most recent edition is by G. Ovio, *L'Ottica di Euclide*, Milan, 1918.

(2) *Ptolemy* (died about 155 A.D.), in his *Optics*, began the study of refraction, and applied the experimental method to this subject. He showed that luminous rays, in passing from one medium to another are deflected, and he attempted to measure the deflection. This work of Ptolemy was written in Greek, and has been lost. It was translated from Greek into Arabic, and, in the twelfth century, from Arabic into Latin. Only the Latin version survives, and its attribution to Ptolemy is doubtful. The best edition is by G. Govi, Turin.

(3) *Alhazen* (Abu Ali Al-Hazan Ibn Alhasan, 965-1038), was an Arab of Basra, who abstracted the work of the older Greek optical writers. He devoted much space and skill to the development of the effects of curved mirrors. He had a fairly clear notion of the nature of refraction, and improved the apparatus of Ptolemy for measuring the angle of refraction in different media. He had

ideas on the structure of the eye that were an improvement on those of his predecessors, but he had little knowledge of lenses, except in connection with that organ. He does, however, refer to the magnifying power of segments of a glass sphere. He considered that vision resulted from rays coming to the eye from the object, and opposed the view, which held the field till the seventeenth century and later, that explained vision as a result of something emanating from the eye. There are editions of Alhazen's work printed in the sixteenth century. These represent a translation into Latin by an unknown writer of the late twelfth or early thirteenth century (*see* 4).

(4) *Witelo* (first half of the thirteenth century) was a Pole, who studied in great detail the work of Alhazen. His own work grew out of this, and is perhaps an improvement on it. Thus he drew up a table of refractions for the three media—air, water, and glass—from which it could be seen that the angle of refraction did not vary according to the angle of incidence. It is doubtful, however, to what extent these tables were original or the results of direct observation. The works of Alhazen and of Witelo were printed together by F. Risner at Bale, 1572. An interesting account of Witelo, together with a reprint of his *Perspectiva* from the MSS. has been recently set forth by Clemens Bauemker in his *Beitrage zur Geschichte der Philosophie des Mittelalters*, Munich, 1908.

(5) *Roger Bacon* (1214-1294) accomplished real advances in the knowledge of optics. His work was based primarily on Latin translations of Arabian writers, and especially on Witelo's version of Alhazen. He is distinguished from his predecessors, however, by his clear conception of the value of experiment, and by the evidence in his works that, having made a serious and continuous effort to discover the laws of the refraction and reflection, he sought to apply his knowledge to the improvement of the power of vision. In this he is a real pioneer, and is in the truest sense the father of microscopy.

But it is easy to exaggerate the claims of Bacon, and the wildest statements are often made about his discoveries. It is a fact that there is no evidence that he ever made a telescope nor any microscope, save a simple one. But he had a clear, though not wholly accurate idea of the nature and properties of lenses, and, groping with the instinct of genius, he did vaguely foresee both telescope and microscope. The following passages will serve to indicate the stage he had reached in optical knowledge. I have purposely selected passages containing some errors. It will be observed that in the first of these passages Bacon refers to and figures the *object* as though it were itself in the denser medium of which the lens is composed. In doing this he is confusing the optical action of a lens with that of a liquid in which an object is immersed. The optical results of immersion in a liquid had been investigated by his predecessors, and were perhaps familiar to Aristotle.

"If anyone examines letters and other minute objects through the medium of crystal or glass or other transparent substance, if it be shaped like the lesser segment of a sphere, with the convex side towards the eye, and the eye being in the air, he will see the

letters far better, and they will seem larger to him. For, according to Canon 5 (*see* Fig. 1) concerning a spherical medium beneath which the object is placed, the centre being beyond the object, the convexity being towards the eye, all causes agree to increase the size, for the angle in which it is seen is greater, the image is greater, and the position of the image is nearer, because the object is between the eye and the centre. For this reason such an instrument is useful to old persons and to those with weak eyes. For they can see any letter, however small, if magnified enough. But if a larger segment of a sphere be employed, then, according to Canon 6

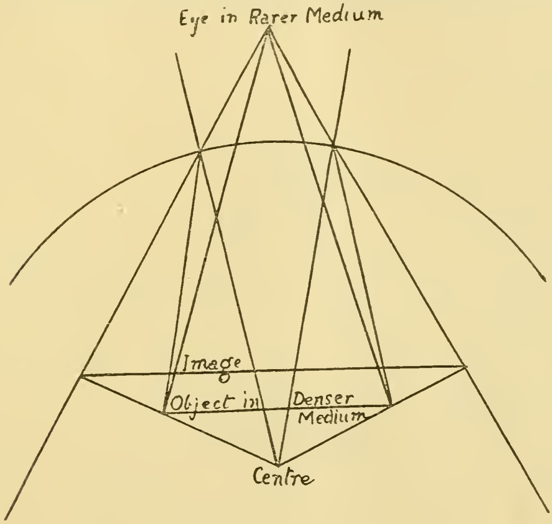


FIG. 1

(Fig. 2), the size of the angle is increased, and also the size of the image, but propinquity is lost because the position of the image is beyond the object, the reason being that the centre of the sphere is between the eye and the object seen. Therefore such an instrument is not of so much use as the smaller portion of a sphere."

"Objects are greater when the vision is refracted; for it easily appears by the above-mentioned canons that very large objects may seem to be very small and conversely, and those at a great distance away may seem very near and conversely. For we can so form glasses and so arrange them with regard to our sight and to objects that the rays are refracted and deflected to any place we wish, so that we see the object near at hand or far away beneath whatever angle we desire. And so we can read the smallest letters or count grains of sand or dust from an incredible distance, owing to the magnitude of the angle beneath which we see them, while we can scarcely see the largest objects close at hand, owing to the smallness of the angle beneath which we view them; for distance does not affect this kind of vision save *per accidens*, but the size of the angle

(does so affect it). So a boy can appear a giant, a man seem a mountain, and in any size of angle whatever, just as we can see a man under so large an angle like a mountain and as near as we desire. So a small army might seem very large, and though far away appear near, and conversely: so too we could make sun, moon, and stars apparently descend here below, and similarly appear above the heads of our enemies, and many other similar marvels could be brought to pass, so that the ignorant mortal mind could not endure the truth." (*Opus Majus*, Part V).

"And what is causally manifest with regard to double refraction we can verify in many ways by the results of experiment. For if anyone holds a crystal ball or a round urinal flask filled with water in the strong rays of the sun, standing by a window in face of the

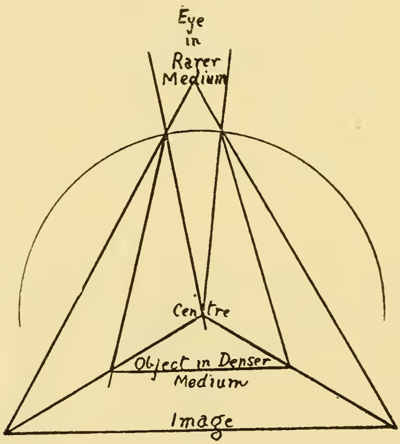


Fig 2.

rays, he will find a point in the air between himself and the flask at which point, if any easily combustible substance is placed, it will catch fire and burn, which would be impossible unless we suppose a double refraction. For a ray of the sun coming from a point in the sun through the centre of the flask is not refracted, because it falls perpendicularly on flask, water, and air, passing through the centre of each (Fig. 3). . . . But all the (other) rays which are given forth at the same point in the sun from which this perpendicular ray comes are necessarily refracted on the body of the flask, because they fall at oblique angles, and since the flask is denser than air, the refraction passes between the straight path and the perpendicular drawn from the point of refraction to the centre of the flask. And when it passes out again into the air, then, since it comes upon a less dense body, the straight path passes between the refraction and the perpendicular drawn from the point of refraction, so that the refracted ray may fall upon the first perpendicular which comes without refraction from the sun. And since an infinite number of rays are given off from the same

point of the sun, and one only falls perpendicularly on the flask, all the others are refracted and meet at one point on the perpendicular ray which is given off along with them from the sun, and this point is the point of combustion, because on it are collected an infinite number of rays, and the concentration of light causes combustion. But this concentration would not take place except by double refraction, as shown in the diagram." (*Opus Majus*, Part VII).

"Glasses (*perspicua*) can be so constructed that objects at a very great distance appear to be quite close at hand, and conversely. Thus we read the smallest letters from an incredible distance, number objects, however small, and make the stars appear as near as we wish. . . . Also objects can be made to appear so that the

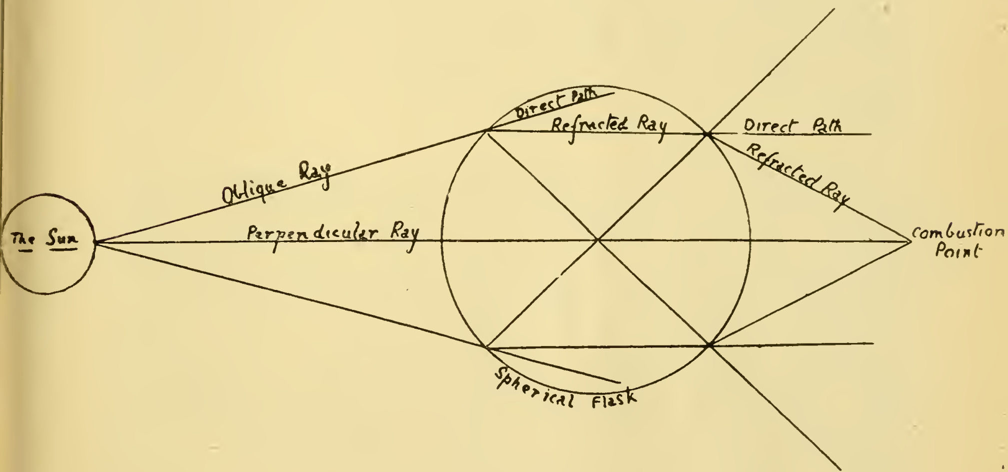


FIG. 3.

greatest seems the least, and conversely; what are high appear low and short, and conversely; and what is hidden appears manifest. . .

But among the more subtle powers of construction is this of directing and concentrating rays by means of (instruments of) different forms and reflections at any distance we wish, where whatever is subjected to them is burned. . . . But greater than any such design or purpose is that the heavens might be portrayed in all their length and breadth on a corporeal figure moving with their diurnal motion, and this would be worth a whole kingdom to a wise man. Let this, then, be sufficient as an example, although an infinite number of other marvels could be set forth." (*De Secretis Operibus Artis et Naturae.*)

It is a remarkable thing that no complete edition of the works of Roger Bacon has ever been prepared, nor any important work by him translated into English. The above passages I have translated from J. H. Bridges, *The Opus Majus of Roger Bacon*, Oxford, 1897, and J. S. Brewer, *Fratris Roger Bacon opera quaedam hactenus inedita*, London, 1859.

(5) *John Peckham* (died 1292), Archbishop of Canterbury, was the author of a work on optics entitled *Perspectiva communis.* His views were very similar to, and, perhaps, taken from, Bacon. He is important only as having drawn wide attention to optical principles. His work exists in a number of manuscripts, and has often been printed. The first edition is dated from Milan, 1482.

(6) The names of Salvino d'Amarto degli Amarti of Florence and Alessandro de Spina of Pisa (both circa 1300) have become associated with the special application of lenses for use as spectacles. Lenses, as we have seen, were known to Roger Bacon, who suggested also their use in aiding vision. D'Amarto and Spina applied the principle thus suggested. From about 1300 onward convex lenses for use as spectacles were well known.

The question of the invention of spectacles has been frequently discussed. One of the latest writers who has traversed this field is V. Rocchi, *Appunti di storia critica del microscopio,* in the *Revists di Storia critica delle Scienze Mediche e Naturali,* January, 1913.

(7) *Leonardo da Vinci* (1452-1519) had sounder ideas than any of his predecessors on the structure of the eye, on binocular vision, on refraction and diffraction. He developed a practical *camera obscura,* and gives a hint of a "glass to see the moon enlarged." His work, though original and valuable, remained inaccessible for nearly four centuries, and had no influence on his contemporaries.

Leonardo left his scientific remains in a state of confusion, and they have suffered much by time and misuse. It is impossible to give a bibliography here, but his optical results are summarised by E. Solmi, *Leonardo da Vinci e il metodo sperimentale nelle ricerche fisiche,* in the *Atti e memorie della R. Accademia Virgiliano di Mantova,* Mantua, 1905, and by O. Werner, *Zur Physik Leonardo da Vincis,* Berlin, 1911.

(8) *Girolamo Fracastoro* (1478?-1553) was a suggestive writer who devoted considerable space to a rather confused account of refraction. In the course of this discussion he has the following passage:—"(Not only the character but) also the position of the medium affects the appearance of the objects seen, as may be observed with spectacle lenses (*in specillis ocularibus*). For if the lens be placed midway between eye and object, it appears much larger than if the lens is made to approach the object or the eye. (*Homocentrica* II, 8). . . . Glasses (*specilla ocularia*) may be arranged of such density that if anyone looks through them at the moon or at any star they appear near and hardly higher than the steeples. (*Homocentrica,* III, 23)." It is possible that he was here contemplating a bilenticular apparatus. The *Homocentrica* in which these passages occur was first printed at Venice in 1538. The scientific value of this work is discussed by the present writer in an article in the *Annals of Medical History,* Vol. I, p. 1, New York, 1917.

(8) *Francesco Maurolico* (1494-1575) was perhaps the first after Roger Bacon to attempt a mathematical analysis of the optics of the lens. He is thus the predecessor of Kepler. His work, *Photismi de lumine et umbra*, was printed at Venice in 1575.

(9) *Leonard Digges* (died 1571?) was the first to whom can be definitely attributed the construction of a bilenticular system. The evidence for this statement rests on the following passage in a work by his son, Thomas Digges (died 1595):—

"Marueylouse are the conclusions that may be perfourmed by glasses concaue and conuex of circulare and parabolicall fourmes, using for multiplication of beames sometime the ayde of glasses transparent, which by fraction should unite or dissipate the images or figures presented by the reflection of other. By these kinds of glasses or rather frames of them, placed in due angles, ye may not only set out the proportion of an whole region, you represent before your eye the lively image of euery towne, village, etc., and that in as little or great space or place as ye will prescribe, but also augment and dilate any parcell thereof, so that whereas at the firste apparance an whole towne shall present it selfe so small and compacte together that ye shall not discerne any difference of streates, ye may by applycation of glasses in due proportion cause any peculiare house or roume thereof dilate, and shew it selfe in as ample fourme as the whole towne first appeared, so that ye shall discerne any trifle or reade any letter lying there open, especially if the sonne beames may come unto it, as playnly as if you wer corporally present, although it be distante from you as farre as eye can discrye. But of these conclusions I minde not here more to intreate, hauing at large in a volume by it selfe opened the miraculous effectes of perspective glasses." Digges's system appears to have been combined in some manner with a *camera obscura*. Unfortunately, his further description of it was never published. The work of Thomas Digges in which this passage occurs is entitled *A Geometrical Practise named Pantometria*, and was printed in London in 1571.

(10) *Gianbattista della Porta* (1540-1615) is the first to whom can be attributed the actual combination of lenses in the form of a microscope. This statement rests on the evidence of the following passages in his *Magia naturalis*:—"Concave lenses enable one to see far off more clearly, while convex ones make near objects more discernible." He was apparently myopic, for he goes on to say that "with a concave lens you see things afar smaller but plainer, with a convex lens you see them larger but less distinct. If, however, you know how to combine the two sorts properly, you will see near and far both large and clear." In later years, when the microscope became a recognised instrument, much larger claims were made by and for Porta, but there is no real evidence that he made any effective practical application of his idea. The *Magia naturalis* was first printed at Naples in 1558, but the passages in question do not occur in it, nor in any edition of the work that appeared before that of 1588.

(11) *Zacharias*, son of Jan, and known as Jansen (1580-16?), of Middelburg, is usually regarded as the first who actually constructed a microscope. His first attempt was the result of an

accident. It appears that while still a lad and at work in the shop of his father, who was a spectacle maker, he happened to place two lenses in a tube and found that they acted as a microscope or telescope. Effective instruments were constructed by him in the first decade of the seventeenth century. The evidence that Jansen was really the first constructor of these bilenticular instruments rests on the testimony of Willem Boreel (1591-1668), the Dutch Ambassador to France. Boreel's evidence is given in a letter by him to Pierre Borel (1620-1671), which runs as follows:—

"I am a native of Middelburg, the capital of Zeeland, and close to the house where I was born . . . there lived in the year 1591 a certain spectacle maker, Hans by name. His wife, Maria, had a son Zacharias, whom I knew very well, because as a neighbour and from a tender age I constantly went in and out playing with him. This Hans, or Johannes, with his son Zacharias, as I have often heard, were the first to invent microscopes, which they presented to Prince Maurice, the governor and supreme commander of the united Dutch forces, and were rewarded with some honorarium. Similarly, they afterwards offered a microscope to the Austrian Archduke Albert, supreme governor of Holland. When I was Ambassador to England in the year 1619, the Dutchman Cornelius Drebbel of Alkomar, a man familiar with many secrets of nature, who was serving there as mathematician to King James, and was well known to me, showed me that very instrument which the Archduke had presented as a gift to Drebbel, namely, the microscope of Zacharias himself. Nor was it (as they are now seen) with a short tube, but nearly two and a-half feet long, and the tube was of gilded brass, two fingers breadth in diameter, and supported on three dolphins formed also of brass. At its base was an ebony disc, containing shreds or some minute objects which we inspected from above, and their forms were so magnified as to seem almost miraculous." This passage is contained in a work by Pierre Borel, *De vero telescopii inventore cum brevi omnium conspiciliorum historia*, The Hague, 1655.

(12) *Jan Lippershey* of Wessel (flourished 1608) is another candidate for the same honours as Zacharias. In October, 1608, a man named Lippershey applied at the Hague for a monopoly in the making of a bilenticular apparatus for examining objects at a distance. Even at that date, however, it appears from the evidence that such instruments were already known. The story of Lippershey's discovery is suspiciously like that told of Zacharias. The application and findings of the committee that sat on it were still in existence in the early part of the nineteenth century, and were published by J. H. van Swinden. *See* S. Moll, *Journal of the Royal Institution*, Vol. 1, 1831.

(13) *Jacob Andrianzoon*, otherwise *James Metius* of Alkmaar, was a younger brother of a distinguished geometrician. Of him Descartes, in his *Dioptrique*, published in 1637, writes as follows:—"It is about 30 years since one named Jacques Metius, an unlearned man, but one who loved to make mirrors and burning glasses, having by him glasses of various shape, thought of looking through two of them, of which one was convex, and the other concave, and he

luckily put them in the ends of a tube, and thus the first telescopes were made." Metius also applied for a patent, and a copy of his application has survived among the MSS. of Christion Huygens (1629-1695).

(14) *Galileo* (1564-1642) was the effective discoverer of the microscope, a discovery which, as in the other cases, was bound up with that of the telescope. The event may be referred to the early part of 1609, and the story may be told in a translation of his own words:—

"About ten months ago," he says, "a rumour reached me of an ocular instrument made by a certain Dutchman by means of which an object could be made to appear distinct and near to an eye that looked through it, although it was really far away. . . . And so I considered the desirability of investigating the method, and I reflected on the means by which I might come to the invention of a similar instrument. A little later, making use of the doctrine of refractions, I first prepared a leaden tube, at the ends of which were placed two lenses, each of them flat on one side, and as to the other side I fashioned one concave and the other convex. Then, moving the eye to the concave one, I saw the objects fairly large and nearer, for they appeared three times nearer and nine times larger than when they were observed by the naked eye. Soon after I made another more exactly, representing objects more than sixty times larger. At length, sparing no labour and no expense, I got to the point that I could construct an excellent instrument so that things seen through it appeared almost a thousand times greater and more than thirty-fold nearer than if observed by the naked eye." (*Siderius Nuncius*, Venice, 1610).

In another work he says: "Some would tell me that it is of no little help in the discovery and resolution of a problem to be first of all in some way aware of the true conclusion and certain of not being in search of the impossible, and that therefore the knowledge and the certainty that the microscope had indeed been invented had been of such help to me that perchance without that I should not have discovered it. To this I reply that the help rendered me by the knowledge did indeed stimulate me to apply myself to the notion, and it may be that without this I should never have thought of it. Beyond this I do not believe that knowledge to have facilitated the invention. But, after all, the solution of a problem, thought out and defined, is a work of some skill, and we are not certain that the Dutchman, the first inventor of the telescope, was not a simple maker of ordinary lenses, who, casually arranging glasses of various sorts, happened to look through the combination of a convex and a concave one placed at various distances from the eye and in this way observed the effect that followed thereon. But I, moved by the knowledge given, discovered it by a process of reasoning." (*Il saggiatore*, Rome, 1623.)

(15) Galileo's account of the path of light in the bilenticular system is unsatisfactory, but was improved by Kepler in his *Dioptrice* (Cologne, 1611), who at the same time suggested that form of microscope consisting of two convex lenses which has developed as our modern instrument.

Professor A. E. Conrady contributed some "Notes on Microscopical Optics," which were communicated by Professor Alfred W. Porter, F.R.S.

NOTES ON MICROSCOPICAL OPTICS.

By A. E. Conrady.

It is manifestly impossible to give an exhaustive treatise on microscopical optics in a short paper, but a brief indication of what has been done and what is likely to be accomplished in the near future may be acceptable.

The resolving and defining power of the microscope depends primarily on the high correction of spherical aberration in cones of rays of very large angular aperture. The first approximation methods which are useful in arriving at preliminary designs of telescope objectives will only give rough indications of the required forms of components even in the lower powers of microscope objectives, and they are quite useless in the case of the higher powers.

Exact trigonometrical ray-tracing must therefore form the foundation of the designer's work. It is not, however, desirable to depend entirely upon this method, for the real desideratum in every lens system is that all the light from an object-point should reach the image point along paths of the same optical length, and according to the classical limit recommended by the late Lord Rayleigh, this equality of optical paths should not be departed from to a greater extent than $\frac{1}{4}$ wave-length, say five one-millionth of an inch. It used to be thought by practical opticians that this represented a perfectly absurd and unattainable degree of perfection, but I showed long ago (Monthly Notices R.A.S., April, 1905), that so far is this from being true that the Rayleigh limit really represents a far more generous allowance, in the ratio of about 4 to 1, than the union of the geometrical rays within a "circle of confusion" equal to the resolving power of an objective, which latter condition was looked upon as practicable. Quite recently the fulfilment of the Rayleigh condition in good telescope and microscope objectives has been put to the direct experimental proof by that valuable innovation: the Hilger Lens-Interferometer. In the paper quoted above I gave a trigonometrically exact method of *determining* the phase-relation in which rays arrive at a focus. I had used the method for about 10 years at the time of its publication, and all my designs of microscope objectives are based on its use: but up to the time when I began lecturing at the Imperial College I was probably the only designer who took advantage of this method, which is not only the soundest from the theoretical point of view, but also by far the easiest and quickest. As it gives the exact amount of spherical

aberration arising at each surface in the absolute measure of wavelengths, it also enables a designer to avoid the unnecessary piling up of huge aberrations such as are met with in the lens systems designed by purely geometrical ray-tracing.

Recently (Monthly Notices, June, 1919), I have rounded off this earlier work by determining the complete light-distribution in the "spurious disc" which results when residuals of aberration are present, so that the designer using the optical path method can now state definitely to what extent the image points obtained with a given system fall short of the full brightness and sharpness which would result in a theoretically perfect instrument.

The chromatic aberration of microscopic objectives is also best and most conveniently determined in terms of differences of optical paths (Monthly Notices, January and March, 1904). By applying the simple formulae to both marginal and paraxial rays, a reliable measure of the higher chromatic aberrations, the so-called spherical variation of chromatic correction, is obtained, and this can then, by suitable alterations of lens curvatures, etc., be kept within those narrow limits which distinguish "semi-apochromatic" objectives from earlier types in which this variation frequently reached very serious amounts.

A microscope objective perfectly free from spherical and chromatic aberration may yet be absolutely useless for practical purposes on account of such amounts of coma in the images of extra-axial object points that sharp definition is limited to an almost infinitesimally small area in the exact centre of the field. One of Abbe's first attempts at the designing of microscope objectives purely by calculation appears to have resulted in a particularly bad specimen of this type. The search for the cause of the defect led him to the independent discovery of the famous "Sine-Condition," also announced almost simultaneously by Helmholtz, and previously discovered—without attracting the attention of opticians—by Clausius. In an approximate algebraical form it also figured as the second of the famous 5 conditions of Seidel. The realisation of its immense value, however, dates undoubtedly from the announcements by Abbe and Helmholtz in 1873. Since that time it has saved an incalculable amount of time and trouble to the designers of telescope and microscope objectives, as it indicates the presence or absence of coma in the central part of the field by a simple comparison of figures taken directly from the trigonometrical computations. I gave a simple and fairly exhaustive proof and discussion of this theorem in Monthly Notices for March, 1905, and to that paper those interested may refer.

If, and only if, the foregoing defects (spherical and chromatic aberration within the Rayleigh limit and coma) are properly corrected, then another defect of all ordinary lens systems will become obvious and objectionable, *viz.*, the secondary spectrum. This is due to the fact that, as compared with ordinary crown glasses, the heavy flint glasses which have to be used to compensate the primary chromatic aberration disperse the blue end of the spectrum too much and the red end too little. The result is that flint lenses of the proper power to secure achromatism for the brightest yellow and green region of the spectrum overcorrect the dispersion of the crown

in the blue and violet end and undercorrect it in the orange and red end. As the crown lenses alone would bring violet to a shortest and red to a longest focus, the effect is that the achromatic combination brings both ends of the spectrum to a longer focus than its central part. Therefore there is a minimum distance of the focus for yellow-green, and at that focus the light from both ends of the spectrum is diffused, and causes a halo of a purple or claret tint. This halo is objectionable even in visual observations, because it falsifies the true colour of the observed objects, but the difference of focus to which it is due becomes a grave defect when the object is to be photographed, unless a strong screen is used which cuts off both ends of the spectrum, but more particularly the dark blue and violet light. Such a screen greatly increases the required time of exposure, and may be inadmissible in the case of stained or naturally strongly coloured objects, because these may be either opaque or too transparent to yellow-green light.

The attempts to produce varieties of *glass* free from this secondary spectrum have been unsuccessful as far as the microscope is concerned, for the existing crowns and flints with proportional dispersion have so little difference in dispersive power that an impracticable number of lenses would have to be used to secure the desired effect. We therefore still depend on the material whose value for this purpose was discovered by Abbe, the natural mineral fluorite, used instead of crown glass in combination with heavy crown glasses or very *light* flint glasses in place of ordinary *dense* flint glass. It was by the use of fluorite that Abbe produced the apochromatic objectives, and fluorite of good optical quality must be used to this day to secure the result. Apart from the difficulty of finding this material there is no obstacle to the designing by exact calculation of apochromatic objectives.

I now come to a defect of nearly all microscope objectives, and especially of highly corrected ones, which is well known to all practical microscopists, namely the pronounced curvature of the field, invariably in the sense of requiring a shortening of the distance from object to lens in order to obtain a sharp focus in the outer parts of the field of view. The general theory of the primary aberrations of oblique pencils shows that any lens system when freed from astigmatism will have the curvature of field defined by the Petzval theorem, and that in the presence of astigmatism the two focal lines which then represent the strongest concentration of the light always lie both on the same side of the Petzval curve and at distances from it which are in the approximate ratio of three to one. When the astigmatism is undercorrected the natural curvature of the field defined by the Petzval equation becomes aggravated whilst overcorrected astigmatism tends to flatten the field, and is deliberately introduced for this purpose in ordinary photographic objectives. The presence of considerable amounts of astigmatism, of course, renders really sharp marginal images impossible in either case, so that its absence or better still a modest amount of overcorrected astigmatism must be regarded as the ideal in microscope objectives. Unfortunately this desirable state cannot be reached in the existing types of objectives. The binary low power objectives up to the ordinary one inch and 2/3 inch come nearest to it, and are therefore justly liked

by microscopists for all work for which they are sufficiently powerful. In the ordinary ternary objectives of the 1/6 inch type, with approximately plano-convex components, the curvature of the field is also of reasonably moderate amount. But it is a general experience that highly corrected objectives are very much worse as regards curvature of field. In the light of my most recent work on the general theory of lenses (Monthly Notices, November, 1919), this curious and objectionable peculiarity is easily explained, and becomes revealed as a *necessary* consequence of high spherical and chromatic correction if the usual number of components is adhered to. In the Lister and Amici types of ordinary objectives, which are fairly satisfactory as regards curvature of the field, the front lens is of such a form as to produce strong outward coma and there is in the back lens or lenses a corresponding amount of inward coma. The simple extensions of Seidel's theory given in the paper last referred to show that this is the state of affairs which tends to diminish undercorrected astigmatism or even to reverse it into the more desirable over-corrected form. High correction of the zonal spherical aberration, and to a still greater extent complete removal of the spherical variation of chromatic correction necessitate a more or less complete reversal of the coma effects in front and back components. In other words, with the usual types of objectives, reduction of curvature and apochromatic or semiapochromatic correction are completely antagonistic and incompatible: what benefits one correction is detrimental to the other. Fortunately the extended theory also indicates a way out of this dilemma. It appears fairly certain that by building the objective itself on the lines required by the apochromatic condition, but leaving it spherically undercorrected, perhaps also chromatically overcorrected to a moderate extent, and with a considerable amount of outward coma (this is the most important), and by correcting these residuals in a *widely separated* additional back lens, it will be possible to combine moderate curvature of field with apochromatic perfection and thus to remove the worst outstanding defect of the best objectives.

Condensers for the proper well-regulated *illumination* of microscopic objects are identical in optical design with objectives, the only difference being that the light passes through in the reverse direction and that a lower degree of correction is sufficient not only on theoretical but also on practical grounds, for nearly always condensers are used in conjunction with the "plane" mirror, which invariably is very far from optical perfection, and so introduces irregular aberrations of unknown magnitude and kind, and moreover the light from the condenser has to pass through the slide on which the object is placed. This slide is practically little better than window glass as far as optical quality and perfection of surfaces is concerned, and the great variation in thickness is another source of imperfection, especially with dry condensers of high N.A.

Moderate amounts of residual aberrations in condensers can always be effectively neutralised by using a sufficiently large source of light of uniform brightness or by magnifying the source by a sufficiently well-corrected "bull's-eye," if the source of light is naturally small.

A great and very serious defect in the construction of nearly all condensers of the present day, with the exception of the modest "Abbe" Condenser of two simple uncorrected lenses, is that the Iris and the ring for dark ground-stops are placed too far from the back lens instead of being close to the anterior focal plane of the condenser. It is easily shown that such a remote Iris-opening or dark ground-stop produces decidedly oblique illumination of the extra-axial points of the object. With direct light this leads to an undesirable variation of the type of image and of resolving power in different parts of the field. With dark ground illumination the result is even more serious, for it is then necessary to use a far larger central stop to secure a dark background over the whole field than would suffice if the stop were placed close to the anterior focal plane of the condenser: such an unnecessarily large stop is highly objectionable, because it reduces the visibility of the coarser structures in the object.

The increasingly bad position of the iris in the condensers of higher power and shorter focal length supplies practically the whole explanation of the universal experience that high-power condensers will not work satisfactorily with low power objectives, especially for dark ground illumination.

The great thickness of the mechanical stage in English stands of the highest quality is the chief *reason* why the iris and "turn-out-ring" of high-power condensers have to be mounted so far below the back lens and a profound modification of the design of the stage with a view to making the part projecting over the condenser as thin as possible therefore appears to be the most desirable improvement of microscope stands from the optical designer's point of view.

In concluding these remarks on the optical design of microscope lenses I wish to point out that the whole subject is adequately dealt with in my lectures and classes at the Imperial College, and that students attending these for two or three years will be turned into competent designers, provided that they have a liking and natural aptitude for applied mathematics, are good at numerical calculations, and of an inventive type of mind.

As regards the *actual making of microscope objectives*, it must be borne in mind that the excellence of a computed lens system may be completely swamped by comparatively slight imperfections of workmanship, and that high accuracy in this respect is therefore of the utmost importance. In lenses of high N.A. computation shows that a departure from the prescribed radii and thicknesses by a fraction of a thousandth of an inch may lead to a notable loss of perfection, and the polished surfaces must also be truly spherical within less than half a wave-length of light. These limits can be easily observed if modern methods of gauging and measuring are adopted, and if all surfaces are polished to accurately made and conscientiously used test-plates. In the later years of my connection with the optical industry quite large batches of lenses used to be made directly from purely theoretical calculations of objectives of new types without any preliminary trials and without any experimental changes in the finished objectives, 95 or more per cent. of which would be found satisfactory in all respects just as they came

from the mounters' lathes. The tools and methods employed in really *manufacturing* lenses on this system were shown by Messrs. W. Watson and Sons, Ltd., at the exhibition at King's College in January, 1917, and will be found described and illustrated in the record of that exhibition.

In old English practice the component lenses of microscope objectives and condensers used to be fixed in their cells by cement of the sealing-wax type. Many old lenses which are still found in perfect adjustment 50 or more years after being mounted demonstrate that the cement may hold the lenses in correct position almost indefinitely: but other experiences, especially with lenses used in tropical countries, suggest that shifting may occur, and it is therefore to be strongly urged that all microscope lenses should be held between metallic shoulders at both ends by being bezelled into their cells, care being naturally required to avoid pressure and distortion through too tight a fit.

A few words may usefully be addressed to the users of microscope objectives. All the higher powers are very sensitive (the more so the more perfect the spherical correction) to the thickness of the coverglass *plus any mounting medium* intervening between object and coverglass, and also to variations of tube-length, and the best result can only be obtained by adapting the tube-length (or the adjustment of the correction-collar if there is one) to the individual coverglass. It is grossly unfair to interchange one objective with another of similar power but different make on the tube-length suiting the objective treated as the standard and then to condemn the new objective (usually an English one!) because it gives an obviously inferior image. It is not even fair merely to find the best tube-length for the new objective, for if the change of tube-length is considerable and in the direction of lengthening, the total magnification will be much higher and the image correspondingly duller and more fuzzy. To make the comparison fair, each objective should be tried at its own best tube-length, and with such an eye-piece as to give practically the same total magnification.

Another point on which users of objectives err to their own detriment is an excess of faith in numerical aperture. I have heard microscopists boast of possessing an objective, say, of 1.43 N.A., whereas somebody else had one of only barely 1.40, and a careful test would show that whilst the 1.43 was an indifferent lens, the 1.40 was excellent. The fancied advantage of 2 per cent., then, is really a disadvantage of perhaps 25 per cent. or more.

One of the few disservices which Abbe did to microscopy was the pushing of the N.A. of dry lenses to .95 and to a lesser extent the increase of that of oil-lenses to 1.40. The extreme marginal zone of the apochromatic dry objectives of .95 N.A. is particularly badly corrected, so much so that the lenses will only bear a solid illuminating cone of about .65 N.A. even on the Abbe test-plate, and that with annular light bringing only the marginal zone into action correction-collar and tube-length combined do not allow of reaching a point of good spherical correction. There is no doubt that Abbe's own earlier dictum still holds, to the effect that beyond about .85 N.A. the higher aberrations become unmanageable unless the free working distance is reduced to a very few thousandths of an inch.

A carefully computed objective of .85 N.A. will bear a full illuminating cone on suitable objects, and can thus realise its fullest resolving power. An objective of .95 with a condenser of .65 has the resolving power of the mean, or of .80 N.A., and is thus actually inferior except for freak resolutions with extremely oblique light. Oil objectives over 1.30 or at most 1.35 N.A. are also of very doubtful added value.

In closing this section I will once more quote without comment an anecdote of Fraunhofer, who received a complaint that a telescope supplied by him, although giving magnificent images, displayed certain fine scratches when examined with a magnifying glass! The reply sent by Fraunhofer is reported to have been:

"We have constructed the telescope to be looked through, not to be looked at."

A few sentences may perhaps be added as to the prospects for further improvements of microscopic performances. I have already stated in the first section that there is a bright ray of hope with regard to diminishing the curvature of field without loss of definition.

Advances in numerical aperture offer very little attraction. Abbe, in my opinion, carried the N.A. too far rather than not far enough, and I am not aware that any notable discovery has been achieved with the few monobromide-immersion objectives of N.A. 1.60 which he designed.

The use of shorter wave-length, *i.e.*, ultra-violet light, is a little more promising. There would be none but technical difficulties in the construction of lenses suitable for this work. But as only very few microscopists would be likely to go to the trouble of working in invisible light and of passing through a long apprenticeship in mastering the difficulties, apparatus of this description would necessarily be extremely costly, as the whole expense of designing and of constructing special tools would fall on a small number of outfits, or possibly on only a single one. And there would still be the grave drawback that the vast majority of objects would be opaque to extreme ultra-violet rays, and would only yield black-and-white outline pictures.

The so-called ultra microscope does not represent any advance in *resolving* power at all, but most decidedly the reverse. It is highly valuable for the detection of very minute particles and of their movements, which it achieves simply by intense darkground illumination, but the structure of the particles remains unrevealed, and only that would amount to an advance in resolving power. The seeing of these minute particles is, in fact, of precisely the same kind as the seeing of stars subtending less than .001 second of arc at night with the naked eye, the resolving power of which is of the order of 60 seconds.

Professor Alfred W. Porter, D.Sc., F.R S., spoke on "The Resolving Power of Microscopes."

NOTES ON THE RESOLVING POWER OF MICROSCOPES.

By Alfred W. Porter, D.Sc., F.R.S.

The question of resolving power was first of all discussed in connection with telescopes; but the problem for microscopes is essentially identical with that for telescopes. The fact that telescopes of large aperture gave smaller star-images than those with small aperture was first demonstrated by W. Herschel (1805) and later by Foucault (1858). The explanation was given in terms of the wave theory of light by Fraunhofer (1823) and by Airy (1834). Owing to the wave structure of light, each image of a luminous point formed by a lens is found (both experimentally and by the wave theory as developed by Fresnel) to be a circular bright disc surrounded by dark and bright rings of intensity diminishing outwards. If there are two bright sources sufficiently close—two stars, for example—their individual discs may overlap; and for a certain degree of closeness the confusion is so considerable that it is impossible to detect the double nature of the source.

Some convention had to be adopted in specifying the limit at which separation between the discs can be appreciated. The convention actually adopted has been based on the fact that if the centre of the image of one star falls on the first dark ring of the other, then the brightest part of the combined image will be a figure-of-eight disc having a faint diminution of intensity at its middle, which reveals its composite character. Now the radius of the first dark ring (as calculated by Fraunhofer) is

$$\frac{1.22\ \lambda F}{B}$$

where B is the diameter of the object-glass and λ the wave-length of the light received. The angular separation of the stars when just resolved (according to the convention) is obtained (in radians) by dividing this by the focal length of the lens. The reciprocal of this is the angular resolving power. Practice has shown (Dawes; E. M. Nelson) that resolution is obtained when the sources are more than 25 per cent. closer than this. It was shown theoretically by A. W. Porter (R. Micr. J., 1908, Part I.) that the true limit (for which there would be no diminution in intensity at the middle of the double image) corresponds to a closeness of the stars for which the intensity curves would cross at their points of inflexion; this limit corresponds very nearly to that obtained from observation.

The question of resolving power is not, however, an exact branch of science. It is the "thing seen" with which we are concerned, and this depends upon who sees. The human element enters; and

in consequence no exact statements can be made. All we can get is rough estimations by which the quality of optical instruments can be compared. The conventional limit probably supplies this desideratum as well as any other, and since it possesses greater convenience, it may continue to be adopted, except, perhaps, in special problems.

The problem of the microscope has been studied specifically by Helmholtz (1874), Abbe (1873), and by the late Lord Rayleigh. The name of the late Lord Rayleigh may be repeated, because he has dealt with the whole problem in all its ramifications in a way which no other investigator has done. In particular may be mentioned the following papers by him: "On the Diffraction of Object-glasses," Coll. Papers, Vol. I., 163 (1872), "Investigations in Optics," I., 415 (1879-1880), "Resolving Power of Telescopes," I., 488 (1880), "Wave Theory Light," III., 47-187 (1888), "The Theory of Optical Images, with special reference to the Microscope," IV., 235 (1896), Ditto (supplementary paper), V., 118 (1903).

The microscope problem possesses several peculiarities which are not met with in stellar observation. In the first place the object is never self-luminous like a star, and much depends upon the character of the light transmitted through the object when it is semi-transparent or reflected from it when it is opaque. Again, the object seldom consists of points (which would be imaged as diffraction discs and rings), but may be isolated or series lines or may be of any other shape; and in each case may be either bright or dark compared with the "background"; each case requires specific consideration. No one has worked these cases out in full except Lord Rayleigh, and reference must be made to his papers cited above for the full investigations. We can deal here only with some general considerations.

In the first place the essential difference in detail between a telescope and microscope arises from the object being near the objective. It becomes convenient to refer to the semi-*angle* that the objective subtends at the object and the distance, e (instead of the angle) between the two sources which are here separated.

Now for two independent points the distance e for which resolution will occur is for a rectangular opening

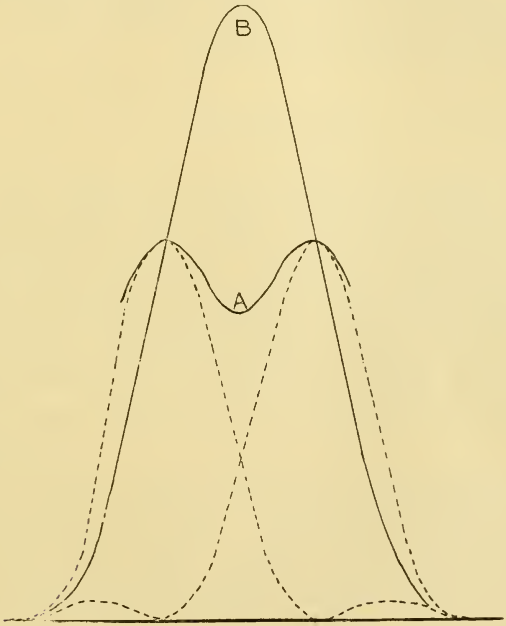
$$e = \frac{\lambda}{2\ n\ \sin a}$$

where n is the refractive index between the object and objective and λ is the wave-length of the light employed. On the other hand, Abbe, by considering a series of linear openings as object, found if the phase of the light passing through each opening is the same for all

$$e = \frac{\lambda}{n \sin a};$$

which is twice as great as before. The quantity n sin a he called the Numerical Aperture, and the reciprocal of e the resolving-power. These two examples bring out a necessary condition for securing fine resolution. The value of e is half as great as when the lights from different points of the object are independent, as when they are isophasal. Now this independence can be fairly secured by focussing a source of light by means of a condenser upon the

object. The condenser itself is an optical instrument to which the principles of resolution apply. The greater the Numerical Aperture (N.A.) of the condenser, the more nearly will each point of the object be seen by light from a distinct point of the source; but perfect independence is never secured. On the other hand, if no condenser is used, or if it be not focussed for the object, each point of the source will send light practically in one phase to a large patch of the object. Other points will do the same. Thus the independence between the lights at different points of the object breaks down, and Abbe's result will be approximated to. That is, for a dry objective ($n = 1$), instead of being able to resolve lines separated by $\lambda/2$ if $\sin\ a = 1$, their distance apart will require to be at least λ. It is this halving of resolving power which is brought about by replacing proper by random illumination.



The difference between these two cases may to some appear obscure. It depends on the fact that the light which passes through neighbouring openings in the object spreads out by diffraction and the diffracted beams overlap in the field of view. If there is no definite phase relationship between these beams the case is analogous to that of illumination by two candles—the *intensities* of light can then be simply added together. When there is a phrase relationship this is not the case. At points where there is an opposition in phase the resultant amplitude may be zero. At intermediate points the phase difference may be zero or a whole number of periods. In this case the resultant *amplitude* is the sum of the separate amplitudes and the intensity is the square of the amplitude. For the sake of illustration two such superposed illuminations are shown in the figure. The dotted curve represents the components placed so that the maximum of one occurs at zero of the other. The

curve A is the resultant when the separate illuminations are independent, while B is the resultant when they are taken to be in the same phase. From A it might be inferred that the object was double from the presence of the two maxima in the resultant curve; in B the two maxima have merged into one and the resolution has vanished.

Examining, then, the case of two bright lines as the standard, it is seen that for a dry objective they must not be closer than half a wave-length for resolution under the best conditions of illumination. For the middle of the visible spectrum this means $e = .000025$ cms. For an immersion objective with immersion medium of refractive index n this should be divided by n. For light of shorter wave-lengths, e is proportionately less. Since this value is calculated (for simplicity) from the assumption that the lens aperture is rectangular, instead of circular, it differs very little from the limit given by the modified definition given by me and quoted near the beginning of this paper.

Magnification.

When an image is resolved it does not follow that it will be *seen* to be resolved. The division marks on a scale may be perfectly separate lines (much more so, in fact, than most optical images); yet they will not be seen separate if placed too far from the eye. It was stated by Helmholtz that they must subtend an angle between one and two minutes of arc in order to be seen as separate lines. In my own case and in those of about ten others recently tested the separation begins at about two minutes, *i.e.*, at shortest distance of clear vision, V, the lines must be separated about $\frac{V}{1800}$. This statement, of course, assumes that the eye can focus the lines in the position at which they are placed either without artificial aid or with the appropriate spectacles. It is also assumed that the illumination is good reading light. If the two lines in the image just resolved by a microscope objective subtend less angle than this, they will not be *seen* resolved. We can calculate, therefore, the limiting magnification necessary. An approximate calculation is sufficient.

With a total magnification of M_1M_2 the size of the image formed by the eye-piece is

$$M_1M_2 \cdot \frac{\lambda}{2}.$$

It is this that must be $\frac{V}{1800}$.

Hence limiting magnification is $\frac{V}{1800} \cdot \frac{2}{\lambda}$

$$= \frac{25 \text{ cms}}{900 \times 5.0 \times 10^{-5} \text{cms}}$$

$$= \frac{10^4}{18} = 555 \text{ nearly.}$$

This is the least total magnification necessary to reveal the structure in the case of this very successful resolution with a dry objective (N.A. = 1); and it is important to observe that it will only just reveal it. Now to see scale divisions well we do not place the scale so that they are only just separable. Even double the angular limit is advisable—and in some cases more. We may safely then take more like 1,000 magnifications for N.A. = 1, and up to 1,500 for N.A. = 1.5. This is precisely one of those data that cannot be definitely stated. We may, in fact, use 10 times the above minimum magnification in certain cases with advantage. But attention must be paid to one consideration in regard to which the graduated scale analogy is misleading. We bring a scale nearer not only to see the graduations easily, but to estimate small fractions of a division correctly. This presupposes that the marks are very fine—much finer than the interval between them. Now, in the image of an object whose structure is comparable with $e = \lambda/2$ there may be detail, but this detail is quite unlike the object. The artificial detail may be made clearer by extra magnification; but if the purpose of the observer is to find what the object is like, and not that of an investigator of the *errors* of optical images, the revelation of this artificial detail is useless and misleading. The only justification for excessive enlargement is when the image is thrown on a screen for inspection by a class, or similarly when a photographic print is made for the same purpose. In these cases it is intended to be observed from a distance; and the useful magnification is then such as will enable the true detail to be seen while the finer false detail will be blurred and inconspicuous. We must, therefore, distinguish between useful and useless magnification. It ought to be observed that it does not matter so far as this question is concerned whether the magnification is chiefly or *entirely* due to the objective. The eye-piece may be dispensed with, as is sometimes done in photomicrography; the calculation will not need any change.

This question should also be looked at from another standpoint. The eye-piece forms an image of the back lens of the objective outside itself; this is the "bright spot," or Ramsden circle. The rays that go through the bright spot are all those which penetrate the objective and are not stopped. The diameter of this spot is approximately $\frac{f}{T} \times$ diam. of back lens of objective, where T is the tube length and f the focal length of the eye-piece. Now in telescopes this can be larger than that of the normal eye-pupil with low powers, and in such a case only a part of the diameter of the object-glass is used. This can only happen with very low powers in microscopy. But with high powers (f small) the bright spot is very small, so that only a part of the pupil is effective. Now Helmholtz concluded that the normal eye-pupil will not bear much reduction without the image seen deteriorating, owing to imperfections in the eye. This point is not easy to demonstrate, because reduction in the aperture of the eye at first improves definition, since the eye is by no means free from aberrations. In my own case a fine line begins to be impaired when the pupil is limited to 2 mm. diameter by an artificial diaphragm. The decrease in sharpness

proceeds only slowly at first, as the diaphragm is further reduced, and it is not until about one millimetre diameter that very considerable deterioration is noticed. The eye is itself an optical instrument. The radius on the retina of the first dark ring of a point source is about 0.01 mm. when the diameter of the effective pupil is 1 mm. This is about eight times the diameter of a retinal cone. But the total magnification

$$M = M_1 M_2 = \frac{T}{F} \cdot \frac{V}{f} \text{ nearly}$$

$$= \frac{V}{F.} \frac{\text{diam. back lens of obj.}}{\text{diam. bright spot}} \;;$$

or taking V = 25 cms. and 2 mm. as the diameter of the bright spot, the magnification becomes

$$M = 125 \frac{\text{diam. back lens objective}}{F}.$$

For the case F = 0.2 cms., back lens = 0.6 cms. diam.

M = 375 diameters.

If we suppose a reduction of the bright spot to 0.1 cm. diam. to be permissible M = 750 diameters.

These results are of the same order as before.

In the case of photomicrography, as we have seen, the permissible magnification is the same whether an eye-piece is used or not. There is the added advantage that the photographic image can be examined *with the eye at best aperture.* On the other hand, there is deterioration in the image due to the grain in the plate, by an amount varying much for different plates. Where the finest representation is required, it should not be forgotten that the old " wet " process could be resorted to; or, failing that, process plates are the next best.

The attainment of as close an approach as possible to perfect images is limited by the extent of the elimination of all the aberrations calculated by methods of geometrical optics. Professor A. E. Conrady emphasises the fact that extension of numerical aperture has surpassed the value warranted by the existing design and construction of lenses. The same may be said concerning condensers even more emphatically. Pioneer investigations on waves of non-spherical form were made by Lord Rayleigh and others. The variation of the intensity in the focal plane of a planoconvex lens has been worked out by L. Silberstein (Phil. Mag., Jan., 1918), who at the same time exhibits the general method by which all such problems can be attacked; and the same kind of question has been worked out by graphical integration by Professor A. E. Conrady (Monthly Not., R. Astr. Soc., June, 1919). Not only are the aberrations of the " lenses " important. The performance of a condenser is modified by the presence of a slide of very imperfect optical quality. So far as its inequalities in thickness are concerned, the errors arising are much reduced by the immersion medium when used with the condenser; a similar remark holds in regard to the objective and cover glass.

With biological specimens the objective " focusses " only a thin layer. If this is near the top of the specimen, the light from the condenser is scattered by the layers beneath; if it is near the bottom

then the same applies to the emergent light. In either case there must be diminution of resolution. In the case of metallurgical specimens these defects are absent. The light is reflected from almost a mathematical surface. It may easily be, therefore, that for such specimens fullest advantage may be taken of permissible magnifying power, especially where the detail is of a simple character. This is seen, for example, in Figure 23 of the contribution by Sir R. Hadfield and Mr. Elliot, where the line markings of Pearlite are very clearly portrayed. On the other hand, in Figures 24 and 25, where there is evidently much fine detail below the resolution limit, it is not clear that the high magnification used is any advantage. Even if this fine detail appeared sharp, it would have no significance.

In the metallurgical case it must be borne in mind that if the mirror or prism in the vertical illuminator is opaque, it blocks out part of the aperture. The resolution of lines (such as those of pearlite) will be different, according to the azimuth in which they lie. Taking the aperture as semi-circular, the character of the image of a point is a central *oval* (instead of circle), the minor axis of the oval being parallel to the bounding diameter of the opening, and about half the length of the major axis (Struve, Mém. de l'Acad. des Sc. de St. Petersburg (7), XXX., No. 8 (1882); Bruns, Astr. Nachr., CIV., 1 (1883); Straubel, Inaug. Disért., Jena (1888); Scheiner and Hirayama, Abhand. Gesell., Berlin (1894); P. F. Everitt, R. Soc. Proc., A83, 302 (1910). Scheiner gives a photograph of the diffraction figure. Everitt gives also a diagram of lines of constant intensity).

Ultramicroscopy.

The considerations of this paper give no indication of the visibility of isolated particles, but only of the possibility of detecting their shape. If each gives sufficient light (either by self-luminosity, as in the case of stars, or by illumination by a powerful beam athwart the line of vision, as in ultramicroscopy), it will be seen. The amount of light it scatters is proportional to the *sixth* power of its radius when it is small compared with the wave-length. Its image is almost independent of its shape under the same condition. Under strong illumination larger particles ($<\lambda$) give complicated diffraction figures; but not much can be learned from attempts to interpret them. The visible disc is certainly much larger than the geometrical image of the particle. Similarly, a luminous line gives an image much wider than its geometric image. This case and that of an isolated dark line of finite width on a bright background have been worked out by Lord Rayleigh. In the latter case, when the background consists of light all in one phase, he concludes that the bar might well remain visible when the width of the bar is only one thirty-second part of the minimum distance between two lines for resolution. The slightly darkened image of the bar has then a width equal to about sixteen times that of its geometrical image and its apparent width is therefore quite illusory. In the case of a self-luminous background (*i.e.*, with phases completely independent), a bar of the same width has only half the visibility of the previous case, but it should be easily recognisable when its

width is one-third of the minimum interval for resolution. He cites the following simple experiment: "In front of the naked eye was held a piece of copper foil perforated by a fine needle hole. Observed through this, the structure of some gauze just disappeared at a distance from the eye equal to 17 inches, the gauze containing 46 meshes to the inch. On the other hand, a single wire .034 inches in diameter remained fairly visible up to a distance of 20 feet or 240 inches. The ratio between the angles subtended by the periodic structure of the gauze and the diameter of the wire was thus

$$\frac{.022}{.034} \times \frac{240}{17} = 9.1."$$

He finds for the proportionate loss of illumination at the centre of the wire in this case

$$\frac{I - I_0}{I_0} = 0.11$$

about what might have been expected.

The moral of these results is the recommendation of caution in interpreting even the width of the bars causing the streaking in microphotographs of pearlite, etc.

Besides the references in the text, the following may be given.

Airy, Tracts, 4th edit., p. 316 (reprinted as "Undulatory Theory of Optics"); Astr. Monthly Notices, XXXIII., 1872; Camb. Phil. Trans., 1834.

Foucault, Ann. de l'Observ. de Paris, t.v., 1858.

Verdet, Leçons d'Optique, t.1, p. 265.

Dawes, Mem. Astron. Soc., XXXV.

Ch. André, Etude de la Diffraction dans les Instruments d'Optique, Ann. de l'Ecole Norm., 1876.

U. Behn, u. W. Heuse, Zur demonstrations der Abbeschen Theorie des Mikroskops. Ber. d. deutsch Physik Ges. 4, 1906, Physik Z. Schr. 7, 750, 1906.

Dr. R. Mullineux Walmsley, Chairman of the Technical Optics Committee of the British Science Guild, outlined the work of that Committee.

I shall not detain you more than a few minutes. I attend this afternoon, as you know, as representative of the British Science Guild, and I thank the President for his kind reference in his Address to that Guild. The Symposium, I take it, and I hope we all take it, will be an epoch marking symposium in the development of the microscope. If it be not that, I very much fear that all the labour which you, Sir, have put so fully into the organisation of this Symposium will not have answered its full object. That being so, however, I think it is only right to the Guild that I should give just the bare facts of its connection with the development of the microscope in order that they may be placed on record in the Minutes.

It was on 14th May, 1915, that the British Science Guild called a Conference of manufacturers and users of microscopes to ascertain what was necessary to secure to the British Empire, and particularly to the British Isles, the trade in these valuable instruments, a large part of which for so long a period had gone to other lands. Great Britain is historically and in many ways the home of the microscope. The Conference met. It was attended by representatives of the leading makers of microscopes in England and by representatives of Government Departments, including the War Office, the Admiralty, the Colonial Office, and the India Office, and by certain well-known private users of microscopes. The necessity for standardisation was the first point discussed, and was very generally recognised; I think there was not a single dissentient. Details were asked for, and a Committee was appointed, which met quite quickly, and elected for its Chairman Sir Ronald Ross, one of the most distinguished users of the microscope that we have. The Committee did not lose much time. The Conference was held in May, the Long Vacation intervened, but the Committee reported in October, 1915. It published, for further discussion, its draft specifications of three types of microscope, one for general use, and not very expensive; another type for advanced pathological work, and a third type for research work. It is not, perhaps, surprising that with a distinguished medical man at its head, the Committee had devoted special attention to pathological work.

These specifications were published, and criticisms came in. It was pointed out that they did not cover the whole ground, and therefore the Guild appointed another Committee to consider what other microscopes should be submitted to standardisation by definite official specifications. A Committee for Microscopes for Special Purposes was appointed, of which I have the honour to be the Chairman. This Committee was appointed in the late part of 1915, and it reported during 1916. The original Committee had confined its recommendations in regard to pathological work to expensive micro-

scopes for advanced and research work. The new Committee, assisted, as was its predecessor, by manufacturers and distinguished users of the microscope—and for their assistance at both Committees the Guild is very grateful indeed—produced a specification for a student's petrological microscope, another one for general use in chemical laboratories, the cost of which was not to exceed £3 at pre-war prices; and, finally, a microscope for metallurgical work, in connection with which it had the assistance of distinguished metallurgists. These specifications were published during 1916 and circulated, but the trade determined that during the continuance of the war nothing could be done in the direction of standardisation until more quiet times came. The interval was not altogether lost, for these draft specifications were subject to criticism, and amended specifications, embodying considered modifications, have been drawn up, which we hope will be satisfactory to the trade and to users. The specifications will be published shortly.

A group of papers on aspects of the manufacture of the microscope was then read by **Mr. Conrad Beck, Mr. F. Watson Baker** and **Mr. Powell Swift**, and discussion on these papers ensued.

A STANDARD MICROSCOPE.

By Conrad Beck.

The British Science Guild having prepared a specification for a standard microscope, we have been engaged for a year in working out the manufacturing processes necessary to produce on a productive scale a microscope that should fulfil the requirements of this specification. The instrument has also certain additional new features which will be appreciated by microscopists.

The stand, limb and body are of a very solid, well-finished type, with the horseshoe base, jointed pillar and Jackson-shaped limb. The base and stage are both coated with a thick surface of ebonite, the body has a larger tube than is customary; the drawtube is graduated, and gives a mechanical tube length of from 140 to 200 millimetres. The standard length of 160 mm. has been adopted for which all object glasses are corrected. The thickness of cover glass for which dry object glasses are corrected is .15 mm., or .006 inch. All object glasses except the very lower power are of such lengths as to be in focus when used on a nose-piece or an objective changer. The fine adjustment is of entirely new design, the two milled heads, one on each side of the limb, are on the same axis, but each milled head actuates a different lever, and thus there are two different speeds, one of which is double as fine as the other, both of which are always in operation. The convenience of this is apparent to those who use object glasses of different powers. A fine adjustment that is sufficiently fine for delicate examinations with 1/12 object glass is frequently troublesome in focussing 1/6 inch.

The action of the slow motion is by a screw with a point impinging on a lever. This method has been considered, and in our opinion correctly so, the only known method of obtaining an absolutely free movement without sag or backlash.

The base of the microscope is provided with three rubber pads which remove vibration, but which can be detached if a rigid contact with the table is preferred.

The instrument is supplied in its simplest form with a plain tubular substage with an iris diaphragm, but this substage can be removed by the microscopist himself and replaced by any of the three more elaborate forms of substage, thus converting the instrument into a complete bacteriological or research instrument.

With the same end in view, a detachable mechanical stage can be attached at any time by the worker himself. All parts are made to standard gauges.

The base measures $6\frac{1}{2} \times 4 \times 1$ inch.

The distance of the stage from the table is $4\frac{3}{4}$ inches, which allows more room for substage apparatus than has been generally given.

The diameter of the mirrors is 2 inches, and they have a vertical adjustment of $1\frac{1}{2}$ inches.

The stage is 4 inches across, and there is a free distance of 3 inches between the optic axis and the limb.

The instrument will carry the ordinary double and triple nose-pieces, but we have taken up a new object glass changer invented by Mr. Sloan, of Birkenhead, which we have found by prolonged use to possess many advantages over a revolving nose-piece, and by putting down tools we have been able to produce it at a very moderate price. The design is so simple and rigid that almost absolute accuracy of centering can be permanently maintained, and the errors of mounting of individual object glasses can be compensated. There are no slides, but the adjustment throughout is made by screwed abutment pins with clamping screws. Once these are adjusted and fixed they cannot shift, and the utmost error we have been able to detect in the alignment of the optic axis by the tightness or looseness with which the clamp by which the object glass and its fitting is secured to the microscope is about 1/6 part of the field of 1/6.

We have introduced a new micrometer eye-piece and a new system of measurement which appears to be in advance of previous methods. The object glasses are all engraved with an initial magnifying power, which is the magnifying power at the first image formed by the object glass with a tube length of 160 mm. We have designed a new vernier scale for measuring objects, with a special positive eye-piece which is entirely above the scale, and when this is placed in the microscope the scale is in the exact position occupied by the image which is formed by the object glass when the medium power eye-piece is used. The object under examination is measured in 1/10 of a millimetre on this scale, and the result divided by the figure engraved on the object glass gives the actual size of the object. If a stage micrometer be placed under the microscope, the initial magnifying power of the object glass may be checked, though this will only be necessary for very exact work. If a Sloan object changer is used, the drawtube must be set to 150 mm., or if a nose-piece is used it must be set to 145 mm. to compensate for the increase in tube length produced by these pieces of apparatus.

At the conclusion of his paper **Mr. Conrad Beck** spoke on "Research in the Use of the Microscope."

RESEARCH IN THE USE OF THE MICROSCOPE.

By Conrad Beck.

In a series of lectures on the Theory of the Microscope which I delivered at the Society of Arts in the years 1907-8, I concluded with some remarks on the necessity for research on the use of the microscope. The methods upon which we now rely for the finest results obtained with high powers and for the best methods of illumination obtained with low and moderate powers are chiefly due to the work in the past of British amateur microscopists who have worked at the subject as a hobby and not as a profession. Now that the simpler problems have been solved, further improvements can only be looked for as the result of a combination of theory and practice which we can scarcely expect from any but trained research workers who can bring to the subject a combination of high optical knowledge and great skill in manipulation. Such work will, no doubt, require the co-operation of the manufacturer, but it is hopeless to expect that the manufacturer himself will have time to devote to the elucidation of the problems themselves. At the present time there are a large number of questions which will have to be solved before any very considerable progress is made in the science of microscopy.

In the lectures to which I refer I indicated, as an example of a possible direction for study, the ingenious suggestion of Mr. J. W. Gordon for reducing the size of the diffraction disc by the use of annular beams of light. This was only one point to illustrate the need of microscopical research. It is well understood that high power resolution depends on the aperture of the object glass, and yet in the new and extremely promising field of work opened up by dark ground illumination, we are deliberately reducing the aperture of our object glass to .9 or even .7 numerical aperture. There is no essential reason why an illuminator could not be devised by which much larger angles could be used in the object glass.

In the study of bacteria by dark ground illumination the diffraction images caused by the micro-organisms are extremely confusing, and there is room for research as to whether these images could not be profoundly modified by different methods of illumination, and to what extent the diffraction images indicate the structure of the organisms.

Another question, which, in my opinion, calls for serious research, is whether and to what extent a wide angle cone of light used in examining a histological specimen reveals or disguises structure, and to what extent the increase in brilliancy of illumination induced by opening up the aperture of the condenser increases or reduces the perfection of the image. I do not think there has been a satisfactory investigation on the examination of this class of

object with different apertures in the condenser when a proper compensating apparatus for keeping the intensity of the light the same with all apertures in the condenser is employed. Neither has there been sufficient attention paid to the question of increasing or reducing the brilliancy of the illumination without varying the aperture of the condenser.

In metallurgical work, the method of throwing the light through the object glass on to the object is undoubtedly very effective, but every convex surface that the light meets in passing through the object glass must of necessity throw back a proportion of the light, thus fogging the final image. There is room for research as to another means of illuminating the opaque objects to eliminate this element of flare and ghost images.

This short paper is written to indicate by a few suggestions that we are more likely to obtain real advances in microscopy by setting up researches on the use of the instrument than by devoting the whole of our time to the discussion of the mechanical details of a slow motion or the most convenient diameter of a milled head. I cannot believe that we are likely at the present time to find a body of disinterested amateurs, with the required scientific training, to take up these difficult subjects. The subjects I have mentioned do not begin to cover the field of research that is required, and if this meeting could be made instrumental in the inauguration of this class of research, it will have accomplished an extremely valuable piece of work.

PROGRESS OF MICROSCOPY
FROM A MANUFACTURER'S POINT OF VIEW.

By F. Watson Baker.

The manufacturer, of necessity, is acquainted with the trend of microscopical development in every direction, for he is beset with suggestion and demand from workers throughout the world. The instruments he designs are largely moulded on his interpretation of such demands.

To a great extent there must be uniformity of design, but the expert, being usually a specialist, finds from experience that methods of work which he adopts as his own entail alterations of construction, and there is a tendency for such workers to attach importance to these details, and to recommend their incorporation in standard models.

It would be a matter of interest to see what the result would be if six independent leading workers were to prepare a specification of an ideal Microscope and Photomicrographic Camera.

English manufacturers have been in a position to meet the varied wishes of their patrons, because much of their work has been done by hand, and whereas with the machine-made microscope of the Continent and America the pattern has had to be taken as it stood, stipulations have invariably accompanied orders for all classes of English microscopes that certain features should be varied to suit the special views of those with whom the order rested.

Manufacturing in this manner has not tended to economic production, and, judging by the fact that it is possible to count all the manufacturers in Great Britain on the fingers of one hand at the present time, it will be fair to assume that such work is either unremunerative or involves difficulty or some disadvantage which discourages enterprise.

Past history reveals the fact that the development of the mechanical part of the microscope especially has been due to the British manufacturer, who has been largely directed and aided by notable progressive workers.

It is therefore not without interest to mention that thirty-eight years ago microscopes meeting fully to-day's needs, both in accuracy of working movements and stability of design, were made in this country.

When apochromatic objectives were first introduced, the only microscope stand on which they could be advantageously used was a British-made one. This alone had a fine adjustment worthy of its name and an efficient achromatic condenser.

Apochromatic substage condensers with means of centering them to the objective, the mechanical drawtube and the incorporated mechanical stage, together with the tripod form of foot, which alone gives stability in the instrument, were first made in this country.

The British maker has always excelled in microscopes of high class, involving skilled hand-work. No instruments in the world to-day vie with the beautiful hand-made first-class microscope stands which have emanated from British workshops.

There is no question that this procedure has been highly approved by expert workers, who found in the best English microscopes the power to use their optical systems with an exactness and variety of adjustment which is not supplied so completely in instruments of other countries.

Students' microscopes, made by the same methods with constant variation, could not compete with standard models made by machinery.

It became evident, therefore, to those who were anxious to establish the English microscope on a sound basis, that a definite model for a definite purpose must be made, and a specification for each type not subject to variation drawn up to the satisfaction of those who directed the purchase and use of microscopes, thus justifying manufacturers in putting down plant for their production in large quantities under economical conditions.

A Committee was accordingly formed by the British Science Guild, consisting of representatives of the many branches of Science and Industry and Government Departments for which microscopes were required, and eventually definite specifications for students, research and other instruments were prepared, which have received universal approval.

This was a great step in a forward direction for the optical manufacturers. Works and manufacturing facilities had grown very substantially during the war, but the hand-workers of the past had been greatly reduced by dispersal and death, and it was no longer possible to make microscopes in sufficient quantity in the customary manner of bygone days. They were therefore able to apply much of their plant and machinery to the production of machine-made microscopes for students' use while reserving for the few hand-workers available the refined special work of first-class instruments.

The amateur, who has not had his requirements satisfied for several years, is pressing for supplies of the best patterns of English microscopes, but the quantity demand comes from teaching institutions, and particularly from medical workers. Of these latter there are a larger number than in pre-war days, and it is believed that the machine-made microscopes on the specifications referred to will be found satisfactory.

On the optical side, the production of microscope objectives and achromatic condensers has been fraught with difficulty. Very little, if any, of the pre-war optical glass remained, and the nearest substitutes had to be used instead, until such time as the British glassmakers were able to give all the varieties that were required for the purpose. Honour is due to them for the success they have achieved in making nearly all the types of glass that have been called for.

Even for a fresh melting of the same glass it is generally necessary, on account of slight differences, to make changes in curves or distances of components, but when several glasses by a fresh

maker are dealt with, the sum of the differences in their constants, although the glasses are of the same *types*, necessitates the complete reconstruction of the objective. This is actually what is happening. It has only been during the last few months that the varieties of glass necessary have been delivered.

The computation of a high power objective usually occupies several weeks, and when this is done, proof plates and tools, which also require great care and a considerable amount of time in preparation, have to be made.

The full programme in this direction has not, therefore, been completed, but rapid progress is being made. The manufacturer is compelled to give priority to the production of objectives that are in most urgent demand, and those which by comparison are not so important will be made in full quantity as time progresses.

If the English microscope is to be firmly established, it requires now the whole-hearted support and recommendation of leaders in this country, and a generous patience while the preparation and supply of all that is needed is taking place.

The technical side of microscopy has, in this country, hitherto depended on two or three men whose names are well known. The means of education in practical optical science have been exceedingly limited hitherto, but it may be hoped that the instruction now being given in this subject will place at the disposal of the optical houses in the near future an increasing number of capable opticians. Such men must possess high technical and mathematical attainments, combined with practical knowledge which can only be obtained in the workshop.

There is one more point. The chief reason why the microscope is not manufactured by a larger number of firms in this country is, not merely on account of its technical difficulties, but because it is regarded as unremunerative. One large optical firm, at least, had microscopes in its post-war programme, but on studying the question, it was found to offer such small prospect of return for the effort and outlay that the project was abandoned, and financial men show no disposition to embark capital in a business of so highly technical a character. So it comes about that manufacturers are thrown very much on their own resources, and it is suggested that progress could be hastened and the whole business in microscope manufacture established in the fullest manner, so that it could stand four square to the competition of other countries, if capital were forthcoming on a generous scale for the purpose.

A NEW RESEARCH MICROSCOPE.

By Powell Swift.

We have, in connection with Messrs. R. & J. Beck, been in consultation with Sir Herbert Jackson and Mr. J. E. Barnard concerning the requirements of a better research microscope for all classes of exacting work than has hitherto been made. This consultation has proceeded only so far as to deal with certain important aspects of the case. We think the advances that are likely to be made in the microscope will be due to constant discussions between the users and the manufacturers of the instruments, and in order that the discussions which have up to the present taken place should be materialised into something definite, we have prepared a model embodying the points that have been so far settled and which should form a stepping stone towards further progress.

Whereas a standard microscope can be produced which may satisfy the requirements of the ordinary worker for a reasonably long period, we do not think that the best type of instrument is likely to remain stationary as long as scientific progress takes place.

Therefore, in putting before you this stand, although we think it marks a distinct improvement due to the helpful suggestions that we have already received, we must take entire responsibility ourselves for the details, and merely express our thanks for the valuable assistance we have received from Sir Herbert Jackson and Mr. J. E. Barnard, without its being supposed that they can be held responsible for an instrument which we have made in order to exhibit at this meeting, without having had time to discuss the final details with them.

The first point which was considered was rigidity, and, while adopting the general principle of our "Wales" model, with its curved limb and radial means of inclination, the casting had been made with a metal tie of great strength to connect the portion carrying the body with that carrying the stage, so that when moving from the vertical to the horizontal position there should be no alteration in focus, due to the slight torsion which is otherwise produced in the curved limb.

The body is 2 inches in diameter, so that a photographic lens placed in its interior enables a large field to be obtained and not cut off by the margin of the tube. A rack and pinion drawtube and supplementary sliding drawtube are provided, so that the mechanical tube length can be varied from 140 to 250 mm. The fine adjustment, which is of the twin side milled head type, is fitted with Messrs. Beck's new double lever adjustment, providing in this manner two very delicate adjustments, one of which is five times as fine as the other.

The entire stage is carried on a very massive right angle cradle, and racks up and down, with all its apparatus for metallurgical work having a travel of $2\frac{3}{4}$ inches. This is more solidly constructed than has been the case with such instruments, so that there shall be perfect rigidity.

The mechanical stage, which rotates concentrically, and is provided with centering screws for adjusting it to the optic axis, is a modification of that of our "Premier" model. The substage introduces an entirely new feature. It is provided with two cradles on the principle of the Sloan Objective Changer, introduced by Messrs. Beck, so that the whole of the substage apparatus, when mounted in interchangeable fittings with centering adjustments, can be instantly inserted in the substage, two pieces of apparatus being capable of insertion at one time. The body of the microscope is provided with a similar cradle, so that nose-pieces of a special character can instantly be interchanged if desired. For instance, the plain nose-piece may be replaced for petrological work with a nose-piece containing an analysing prism, Bertrand lens, quartz plate, etc., or with a nose-piece containing a high power vertical illuminator or other apparatus. The advantage of this system is applicable also to a great deal of physics research, as by introducing special apparatus into the substage or nose-piece, as occasion may require, a most perfect optical bench can be produced for general experimental work. There is a considerable class of delicate optical research which calls for an optical bench possessing the perfect adjustments of a microscope, and we believe that hitherto this requirement has not been met. By examination of the instrument it will be seen that almost any class of apparatus could be applied to the stand for making small and accurate measurements in physics, and although the chief object of this instrument is to provide the most perfect microscope that can be required, the other function for such an instrument has been borne in mind.

The base of the microscope is of the English tripod pattern, but has been provided with a new feature which is specially useful for photomicrography and optical bench work, which will also be appreciated by the ordinary observer. A hook shape casting is supplied which can be screwed down to the bench or camera, and an eccentric bar passing through the centre of the base will slide underneath this hook, when, by a slight motion of a lever at the side, the base of the microscope is locked firmly down in an exact position. Another lever between the uprights of the base clamps the joint by means of a right and left hand screw.

We have not alluded to the rack and pinion adjustments of the body, the stage, and the substage, which are of the usual spiral type, but might well call attention to the great width of the slides employed to give great stability to these adjustments.

It was decided in the consultations which took place towards the production of this microscope that while Messrs. Beck were employed on their standard instrument, we should undertake the manufacture of this special type, which would in all probability be sold by both the firms by which it is manufactured.

General Discussion.

The Chairman invited discussion on the group of papers just presented, and he called on Mr. Barnard to make an announcement.

Mr. J. E. Barnard: The point that I wish to raise will only take a few moments. It is this, that Messrs. Swift, I understand, have quite recently manufactured a series of apochromatic objectives. There is no particular innovation in that, because they have made them for years, but I believe that they admit that in some small particulars they come short of the German standard. They are so conscious of the superiority of these new objectives, however, that they are anxious that a Committee should decide as to whether these new objectives are the equals, and we sincerely hope we may say the superiors, of those of German manufacture. For this purpose, therefore, they have suggested, and after consulting with Sir Robert Hadfield we have agreed, that a Committee should be asked to adjudicate upon them, and therefore Sir Robert Hadfield, as President of the Faraday Society, the Presidents for the time being of the Royal Microscopical Society, the Optical Society, and the Photomicrographic Society, and perhaps such an eminent authority in the application of objectives to metallography as Sir George Beilby and one or two others, are to be asked to go into the question of the actual value of these objectives. I feel quite sure that that is a proposition that will appeal to the meeting for the part it will play, apart from any other question, in perpetuating the work of this Symposium. Therefore, even if the results arrived at are not all we hope, this Committee and its conclusions will form a very valuable connecting link between this Symposium and any succeeding work. I therefore have pleasure in moving that this Committee be authorised to proceed with this question.

Mr. F. Watson Baker (Messrs. W. Watson and Sons): May I enquire whether apochromatic objectives of other English firms can also be included? We have made apochromatic objectives for some years, and are quite willing to submit them.

Mr. Barnard: I should say there is no question about that. The reason I brought this up was that Messrs. Swift are the only ones who submitted objectives under the conditions set out, but if any other firm is in the position to submit some, the Committee will be only too anxious to consider them.

Dr. R. Mullineux Walmsley: I am most interested in this question from the educational side. One of the main questions before the Symposium is the production of microscopes in large quantities, and I venture to suggest that, as Mr. Watson Baker says at the end of his paper, the colleges concerned must give him the necessary

men for that work. I take that to be an absolute condition if we are to turn out instruments of high precision of this nature in quantity. The key of the situation lies in the inspection room of the factory, and unless the inspection room is adequately staffed with thoroughly trained men, the microscope manufacturers of this country cannot hope to rival what has been done—to which I refer with some diffidence in the presence of the President—in the engineering industry. Every engineer knows that the production of apparatus and machinery by the engineering industry—high-speed steam engines and things like that—has been due to efficient inspection by highly trained men in the inspection department. Parts are made in quantity, and are interchangeable, and the thing to aim at is to take the parts from store and have them fitted together without further adjustment by skilled workmen, and so to produce the finished article or machine. If the inspection department does its duty, we need not fear the competition of America or of France, both of which will be more serious than that of Germany in the near future; we need not fear it at all. The British microscope will then stand before the world and hold its own.

Lieut.-Colonel Gifford: In my experience I have worked out a good many apochromatic combinations, chiefly for telescopes, but I have never found any three glasses which gave a sufficiently long focus for microscopic objectives. That has led me to believe that the so-called apochromatic objectives for microscopes, excellent as they are, are not true apochromatics; I mean lenses which combine foci for three different portions of the spectrum. Whether that is so or not, I do not know, but I have met many people who know something of the subject who confirm me in this opinion.

Instructor-Commander M. A. Ainslie: This matter of the apochromatic objective has been occupying my attention for about 12 years, mainly from the point of view of what they would do in the resolution of very fine structure, and from the point of view of comparison between different types of objective. What put it into my mind to address the meeting was the fact that Mr. Swift just now was referring to his own objective. Mr. Swift a year or two ago was good enough to send me two 4 mm. objectives, one of which was entirely the equal of a perfect Zeiss 4 mm.; and I have some knowledge of Zeiss 4 mm. objectives, because I have used 18 of them on the same specimen, and I know that specimen by heart. One of the objectives sent me by Mr. Swift was fully equal to anything that Zeiss had done, but the other one was not. I presume that our English opticians are working, so to speak, to a standard. I know that they can turn out work which is in every way as good as anything that has ever been turned out in other countries; but while Continental opticians seem to have a habit of turning out what I might call objectives of 80 to 85 per cent. perfection, our English opticians seem sometimes to turn out something which is very fine—95 per cent.—but they often also turn out something which is about 60 per cent. perfection. In my experience in an amateur way, I have tested a very large number of immersion objectives, and of dry objectives with apertures from .4 to .95. I am

bound to say that the English and other opticians I have had the pleasure of dealing with have put these lenses at my disposal without stint, but I feel that we want to strike a far higher average of excellence. We do not want 95 per cent. perfection in 10 per cent. of the cases, and the remainder under 60 per cent. We want to strike a 90 per cent. average and depend upon it. I want to mention that point because of apochromatic objectives which I have seen made by English manufacturers. I can single out a 4 mm. of Mr. Swift's, a 4 mm. .85 aperture of Mr. Watson Baker, and a 2 mm. of Mr. Watson Baker. I cannot tell you much about the latter, because I do not know what became of the lens, but it was a very perfect one indeed. I can fully echo any remarks that have been made as to the high quality of possible work of English opticians, but I also should like to mention that I wish they would always do it.

Dr. E. C. Bousfield: The few remarks that I shall make to-night have been prompted by what has already fallen, especially from Mr. Barnard, with regard to apochromatic lenses. I think perhaps my experience of them is longer than that of anyone here, since, in conjunction with my friend, the late Mr. Lees Curties, whose loss so many of us deplore, the first photographs made in this country with Zeiss apochromatic lenses were made in my own house, on a dining-room table, incidentally with the tunnel built up with books between the microscope and the camera, and the result was perfectly satisfactory. I think success in this matter depends comparatively little upon the brasswork, but a great deal upon the glasswork, and almost most of all upon the operator. The apochromatic lenses which were at first supplied were of the finest possible quality. I think I have seen nothing better than the first 2 mm. apochromatic lens which I had from Zeiss, but, unfortunately, as was the case with all these early lenses, the glass was very soon attacked by the atmosphere, and in substituting a glass which was more resistent, the qualities of the lens suffered very considerably, and when it was returned to me the field was very much less flat than it had been in the first instance. There is one maker who has not been referred to to-night, but who was absolutely, I believe, the pioneer of apochromatic lens work in this country—I mean the firm of Powell and Leeland. Certainly they turned out—and I say it without any disrespect to anyone else—the very finest work in the shape of glass-work that has ever been used in the world, and British glass-work has been of remarkable excellence. They supplied me, for trial, with an apochromatic lens of their own manufacture, which was calculated in England and made in England, and it was absolutely perfect, but it had the same fault that the Zeiss lenses had, in being made of unstable glass. None of the 2 mm. lenses that I have seen made of the more resistent glass are at all free from roundness of field. I notice that in one of the papers that is to be laid before us reference is made to this roundness of field, and in actual working, those of us who have tried it with, say, 1,000 diameters, will agree that it is a very serious trouble indeed, and I do not see any way of getting over it. Lower magnification and a longer camera does not do so. I suppose the reasons are mathematical ones, which are beyond me.

I can only state the fact that if you get the same magnification with, say, a $\frac{1}{2}$-inch lens and a long camera that you were getting with a $\frac{1}{4}$-inch lens and a short camera, you will hardly get more flatness of field in the one case than in the other.

There is just one other point, and that is that in all the photomicrographic apparatus which I have seen and possessed, there is one fault which seems to be inseparable from the instruments, and that is, with an extended camera, the connection between the operator and the focussing portion of the microscope, especially with lateral focussing milled-heads. These are extremely convenient, no doubt, for bench work in the laboratory, but for ordinary purposes of photomicrography it is extremely difficult to connect them satisfactorily with any form of extended focussing arrangement, and in any photomicrographic apparatus which may be put forward that point should certainly be kept in mind. The most efficient contrivance, I think, that I have ever seen—and the hint may be of use to some here, perhaps—was that of my friend, Dr. Neuhauss, of Berlin, who was well known as one of the very first photomicrographers in Germany. He simply carried a straight arm down from the axial focussing head of the fine adjustment, and attached a string to the lower end, with a weight on one side and a drum on the other, and so he managed to get his focussing fairly accurate. In conversation with Dr. Czapski once, when he came to see me, I pointed out to him that I found it impossible to get accurate focussing without tapping the bench, to make sure that the last adjustment was as delicate as possible, and he said, " Oh, that is quite the regular way for giving the final touch in delicate measurement "; so that I presume I had not gone very far wrong.

Lieut.-Colonel Gifford: I have in my possession two of these early Zeiss lenses. The late Mr. C. Lees Curties procured them for me at a very early period. One is marked No. 2, and is a 6 mm. of 0.95 N.A., and the other is a 3 mm. of 1.40 N.A., and is marked No. 34. Neither of them have suffered in the slightest, and I use them to-day as well as I did originally. On the other hand, I have Powell objectives. One of them is a 1/10 of 1.5 N.A.—a very large aperture indeed—and the other is 1/20 of the same N.A. The 1/10 became entirely obscured about two or three years ago. That, however, has been renovated by the present Mr. C. Lees Curties. The other one, the 1/20, has stood all through. At the same time, if you compare the two makers, I am afraid we must prefer the Zeiss. Both lenses which I possess of that make are simply perfect; I suppose they could not be quite perfect, but they are as perfect as they possibly can be. They stand any power you like to apply to them.

Dr. W. Rosenhain, F.R.S.: I want to draw attention to one particular point about the discussion which has impressed itself upon me in listening to it, and that is that there seem to be two totally distinct questions being discussed in a rather confused manner. The one is the question of establishing a commercial and industrial production of microscopes by mass production. This is, no doubt, a very excellent and valuable industrial step, with which, of course,

every sympathy, and I wish it every success, and shall be glad to do anything to assist it. That is one thing, but the progress of the microscope as an instrument of research and an instrument of precision is quite another thing, and we must not forget the one in view of the other. It was particularly gratifying to find that whilst two of our manufacturing friends were good enough to come here this evening and to speak almost entirely of mass production, the third gave us some prospect of work which was directed towards achieving the best possible that could be achieved, and I hope that it will not only receive the acknowledgment which I am sure it will deserve at the hands of all users of the microscope, but that all manufacturers will feel, I think I may say, that it is their duty, to look after that side of the thing, just as much as to send out a cheap microscope by the thousand; I hope they will succeed in both.

Mr. A. C. Banfield (*Communicated*).

War considerations and other matters have prevented any active participation on my part in things microscopical for the last five years, yet, once having used a microscope, it is impossible entirely to lose one's interest in this important aid to scientific research.

One of the main objects of this Symposium is to suggest possible means of improvement to this instrument, and I will confine my remarks entirely to certain points which have occurred to me at various times.

(1) It is the custom at present, in all high grade microscopes, to supply them with two slides, which carry respectively the coarse and fine adjustments. This is an expensive form of construction, and as I am one of those persons of opinion that very little is mechanically impossible, it should be possible to eliminate one of these slides, making the single slide do duty for both adjustments. Also, as constructed at present, the fine adjustment slide is nearest to the limb, thus causing the delicate micrometer screw or lever to carry the weight of the parts necessary to operate the coarse movement in addition to that of the body tube—the only part the fine adjustment should move.

(2) It is hard to explain the preference which undoubtedly exists in this country for the tripod foot, rightly termed the "English" foot, for it exists in no other country. Many English manufacturers enthuse on "the beautiful hand work" to be found in their instruments, and I imagine that the tripod foot is especially designed to show this off. Now the universal trend in all modern manufacturing is to eliminate entirely all possible hand work; nothing adds more to the total cost of any article than operations which have to be carried out entirely by hand. My indictment of the tripod foot is that it is of a shape which is difficult to cast, and impossible to machine. It is, furthermore, very bulky, and seriously interferes with the efficient operation of the sub-stage when the microscope is in a vertical position. A greater rigidity is claimed for this foot; this certainly is correct if one wants to lean on the instrument, otherwise there is no advantage over the horse-shoe foot, resting on its three milled pads.

(3) In most microscopes that I have used, the slides have been located in a position too near to the stage; the Continental makers are the worst sinners in this respect. The result of this practice is that when an object is focussed, the body tube has to be very considerably racked out, so that the slides only engage for about a third to half of their possible bearing. This does not add to the rigidity. The instrument should, of course, be designed in such a manner that with an objective in place on a changer, and focussed on an object, the male and female elements of the slide should be in complete engagement throughout their length.

(4) Even at the present state of mechanical advance, makers are still to be found preaching the virtues of the sprung slide. In the whole world of mechanics there is no more horrible device than this. It is supremely inaccurate and unreliable, and is merely adopted as an expedient to cover a state of residence in the dark ages of mechanics. Incidentally, I may remark, there seems a strange disinclination on the part of instrument makers to adopt modern manufacturing methods, the broaching machine, with the wonderful possibilities it holds out in the direction of dovetail and other slides, and eye-piece fittings appear to be quite unknown. Again, take such a simple job as a body tube. The common practice is to skim this in a bench lathe, then with the aid of a file and French cloth bring it to the lacquering stage—a tedious job, taking *quantum sufficit*, according to the workman. The whole job can be done on a modern grinder in a minute and a-half.

(5) Regarding the oblique illumination of metallographic specimens under high powers, it occurs to me that advantage may occur by reviving that old idea of fifty years ago in a modern form. If a glass rod, say a quarter of an inch in diameter and four inches long, is taken, and the ends squared and polished, it will serve to convey light from a source to an object with practically no loss. One end may almost touch an open arc, for instance, thus gathering rays at a high angle. These rays are carried along the rod by internal reflection (there is no need to silver the rod externally), emerging at the far end in a beautifully diffused bunch. This is no novelty to most of you, but I suggest that a variation of this idea may be of use in metallography. Take a worked slip, like a small Lummer plate, say 4 mm. wide and $\frac{1}{2}$ mm. thick. On one end balsam a hemi-cylindrical lens of 3 or 4 mm. radius. The other end can be introduced well under an immersion objective, not quite under but probably far enough. For this purpose, the slip would have to be silvered, except at the ends, otherwise the light would leave the slip at the first contact with the oil. At the other end, parallel rays are directed from some powerful source. I merely suggest this expedient for your consideration, as there appears to be a necessity for it at times.

(6) I have no practical acquaintance with metallography, but a specimen was sent to me a few days ago by a Sheffield firm. Now this specimen is distinctly spherical, and if specimens of this description are the rule and not the exception, I do not wonder that

complaints "that the objective has not a flat field" are so common. The objective is computed for a mathematically flat object; if the specimen deviates from a true plane, then definition is bound to suffer. I merely refer to this point because it suggested to me an idea which it may profit some capable mathematician to investigate, which, briefly, is this:—

It is just as easy to prepare a metal specimen, worked to a definite radius, as it is to work it to a plane. Unfortunately, I am not a mathematician, but I suggest that by adopting some small concave radius for a metal specimen, say 10 mm., it may be possible greatly to improve the metallographic objective. The improvement may possibly take the form of a greatly simplified construction, or it may prove a means of increasing the N.A. of a lens. Personally, were I capable of it, I should compute it first of all unachromatised for use with the well-known Mercury line 5461, a powerful source of monochromatic light easily isolated. It could, if it showed promise, be further computed (all fluorite construction) for the powerful ultra-violet radiation at 1851. This would bring the N.A. for a 2 mm. lens to somewhere about 3.5.

(7) I have suggested the above (under 6) as a possible source of an improved objective for metallurgical purposes, but by working a specimen to a radius, it is possible to compensate an apochromatic or other objective which lacks flatness of field, by applying the well-known sphereometer formula.

Take a ruled stage micrometer, focus the centre of the field, and note reading on micrometer drum of the fine adjustment, after which take the reading of the alteration necessary to render the lines at the edge of the field sharp. Then if S is the semi-diameter of the circle in the object plane represented by the field of view, we can immediately say that if the object be given a curvature whose radius is

$$R = \frac{S^2}{2d}$$

the field of view will be in focus simultaneously at the centre and margin. d is, of course, the difference between the two readings of the fine adjustment drum.

A further group of papers dealing with various general aspects of microscope design and construction, presented by **M. Eugene Schneider, Professor Alexander Silverman, Dr. R. E. Slade and Mr. G. I. Higson,** and **Mr. R. J. E. Hanson** were taken as read.

NOTES ON THE FUTURE OF THE MICROSCOPE.

By Eugene Schneider.

A. Mechanical Improvement.—It is very difficult to make precise suggestions as to mechanical improvement. The stands of the different constructors are approaching a type, which in a measure, tends to become classical. The initiative will in this development apparently have to be taken by the scientists and industrials. They will point out to the designers the defects of their instruments, and will indicate the modifications which technical progress requires. Yet we may specify one detail of improvement which might easily be realised. For a long time all designers have adopted the standard "universal screw" for the objectives. Nothing analogous has yet been done for the tubes in which slide the eye-pieces and condensers. This is frequently a matter of inconvenience to the microscopist, who possesses several instruments or who wishes to fit eye-pieces and condensers of different styles into his microscope and stand.

B. Optical Improvements. a. Eye-pieces.—As regards the optical parts, the microscopist, whatever his speciality, has all the necessary instruments at his disposal. At the outside, one might wish for eye-pieces of larger field for dissection or for the study of larger slides. That however, would necessitate a larger tube diameter. The field of the actual objectives is, moreover, of considerable curvature already, and one would gain little by trying to carry the observations to parts far away from the central portion.

b. Objectives.—Abbe has shown that the definition of the microscope is limited by diffraction effects, not on the edge of the objective, but on the object. He has established that the definition—which is frequently styled resolving power—is proportional to what he has termed "the numerical aperture," which he defined by the expression: numerical aperture = n sin u. There u is the semi-angular aperture, that is to say, half of the apex angle of the cone of rays passing through the object and admitted into the objective (Fig. 1), while n is the refractive index of the medium surrounding the front lens of the objective. More strictly expressed, n is the index of the least refractive substance which is found between the object and the second element of the front lens.

But n is a function of the wave-length. In order to increase the numerical aperture, and at the same time the theoretical range of definition, we may hence increase u, or increase n, or decrease λ

Dry Systems of Objectives.—The object itself is immersed in a medium of some refractive power, water, glycerin, Canada balsam, etc. But a cushion of air is always left between the cover-glass and the lens. As the refractive power of the air is taken as unit by opticians, the n in that cushion has the value 1, and hence the numerical aperature is equal sin u. In certain dry systems of apochromatic objectives, the numerical aperture attains the value 0.95.

which corresponds to an angular aperature of 144° (compare Fig. 2). To go further in this respect appears to be impossible. On the one hand the rays would no longer issue from the point lens; on the other hand, the most oblique rays like OI. (Fig. 2) would strike the first dioptric plane at almost grazing incidence, and the losses by reflection would become very considerable.

Immersion Objectives.—Keeping the angular value of the aperture constant, the immersion increases the magnitude of n (Fig. 3). Cedar wood oil (n=1.52) is mostly made use of; it is interposed between the glass cover and the front lens. The numerical aperture may be raised to 1.40. In the great majority of cases nothing will be gained by exceeding this limit. Medical men, botanists, histologists and bacteriologists study their specimens when immersed in water, glycerin, salt solutions and, more rarely, Canada balsam. Only in this last-mentioned case they really utilise the total numerical aperture of their objective. For instance, when the object is placed in water, with a numerical aperture of 1.40, we have numerical

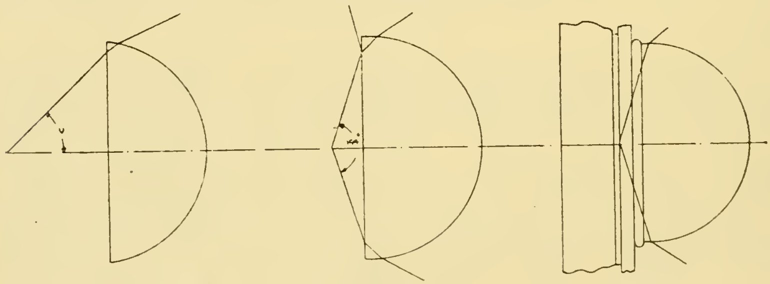


FIG. 1. FIG. 2. FIG. 3.

aperture utilised = 1.33/1.52 of total aperture = 1.22. The *conclusion* to be drawn is that, taking into consideration *only the theoretical definition* and the customary practice, one may say that the microscopic definition has already reached its limit. We have not referred to the variation of λ ; that point will be discussed when we pass to microphotography.

Special Cases. (*a*) *Diatoms.*—For diatoms and in general for very fine and refractory objects, we can make use of a medium and an immersion liquid of very high index. For the silica test of diatoms, *e.g.*, we can apply a solid medium of relatively high melting-point, as silica will stand high temperatures. In this way Zeiss has arrived at an objective of a numerical aperture of 1.60 in making use of a dense flint (for slip and cover) of monobromonaphthalene (immersion fluid), and a solution of arsenic sulphide in bromine (as medium). There again we seem to have reached the limit.

(*b*) *Metallography.*—In metallography the immersion liquid touches the object directly without interposition of any lamella. In this case there is no theoretical reason against the application of extreme numerical apertures; unfortunately the illumination problem becomes particularly difficult.

Aberrations.—To a certain numerical aperture corresponds a certain limit of definition. But this limit is not always attained; in most cases aberrations distort the image, and the microscope proves inferior to what one might hope for.

Spherical Aberration.—This aberration can, in general, fairly well be corrected for a given radiation. The properties of the aplanatic points in the front lens facilitate the task of the constructor in a singular measure. When we consider rays of one colour only, there is little more to be achieved from this point of view with well-constructed objectives.

Sine Condition.—This condition—which says that, central aberration having been corrected for, the point images outside the axis are exempt from coma—is equally satisfied in all good instruments.

Curvature of Field.—As regards flatness, everything, or nearly everything, remains to be done. The field of better-class objectives is curved to a deplorable degree, so that it is impossible to make a useful observation on the borders of the field when adjustment is made for the central portion. The manipulation of the micrometer screw no doubt admits of rapid focussing and facilitates the successive exploration of different portions of the field. Yet there remains a loss of time and a certain difficulty in steadying the ensemble. The defect becomes more pronounced in photomicrographic work, though it can be mitigated by the aid of a projection lens, suitably corrected. But one must not indulge in illusions. As matters are and with the materials at the disposal of the optician, it is impossible to assert that we shall some day succeed in completely correcting for curvature of field.

Chromatism.—Chromatism is never eliminated, though it may be toned down. The so-called achromatic objectives, cut out of the customary glasses, always show more or less troublesome coloured fringes on the outlines of objects. Much has been written about the correction for n radiations by the aid of n glasses. When several conditions are written for achromatisation it can easily be recognised that the roots are real only for certain values of the co-efficients of partial dispersions of the glasses. In the very simple case of two glasses we may write: $$\frac{\phi_1}{\nu_1} + \frac{\phi_2}{\nu_2} = 0$$

or in another form $$\frac{\phi_2}{\phi_1} = -\frac{\nu_2}{\nu_1}$$

where ϕ_1 = the focal power of the convergent lens, ϕ_2 = the focal power of the divergent lens, ν_2 = the ratio of $(n_2 - 1)$ to the dispersion between the two radiations to be achromatised:

$$\nu_2 = \frac{n_2 - 1}{n_2'' - n_2'}$$ for the divergent lens,

and ν_1 = the same ratio $\frac{n_1 - 1}{n_1'' - n_1''}$ for the convergent one. If we possessed pairs of materials such that the ratio were independent of the chosen interval, we might with two glasses achromatise all the radiations. The pupils of Abbe have worked out this problem. The Jena glassworks have produced materials which satisfy the condition defined above *imperfectly*, but *better than the usual glasses.* The term *apochromatic* has

been reserved for these instruments. Unfortunately the new flints, the telescope flint, boro-silicate flint, borate flint, etc., have small dispersive power. The lens curvatures have to be exaggerated, the zonal aberrations become disturbing, their correction is troublesome, the objectives are difficult to construct, and, in spite of their very real superiority over the ordinary achromatic objectives, the price of the apochromatc sometimes makes the buyer hesitate.

In our opinion, the progress of the microscope, as to *easy and compact correction of aberration, will depend much more upon the work of the glass-maker than upon the calculations of the optician.*

We can now form a clearer opinion concerning the interest which extreme magnifications of 5,000, 10,000 diameters and more can present. On Abbe's theory M. von Rohr has fixed the smallest distance that an objective of aperture 1.40 can resolve at 0.00015 mm. The eye can separate about 1 inch, say 0.1 at a distance of 33 mm. An enlargement of 700 diams. enables us to see all the details of an object. A more powerful eye-piece only enlarges the image without bringing out any further detail. The image which the observer examines may be less perfect than the normal view; on the other hand, the eye is fatigued by being strained to its maximum effort. For this reason, one has gone up to enlargements of 2,000 and 3,000 diameters. This latter magnification is excessive, however, and we have never seen it applied for any useful purpose in microscopy. In microphotography, on the other hand, it is sometimes serviceable to magnify 10,000 times and to use even higher powers—for instance, when the image is to be exhibited in the lecture theatre, or when one wishes to touch up a proof or to put references on it.

Photomicrography.—So far we have presumed working in ordinary light. As the photographic plate is sensitive to ultra-violet radiations, we can in photomicrography obtain higher definition by diminishing the λ. One difficulty creeps up at once, however: most of the optical materials are opaque to ultra-violet radiations. Rohr built up the whole optical system out of fused quartz; there was no correction for chromatism, and illumination was effected by one of the aluminium radiations. The index of quartz for D rays is $n=1.54$; for the ray AI_{32}, the index rises to 1.69. The immersion liquid is glycerin; one is, in many cases, restricted by the opacity of the preparation itself. In these respects the limit seems to have already been attained, or nearly been attained.

Condensers.—As regards condensers, the constructors may be said to have preceded the microscopist. For delicate researches, non-corrected condensers are frequently used; yet they should be achromatic. The theory of Abbe assumes that the object is placed in the image of the luminous source. That is, with ordinary condensers, obviously possible only for one single radiation, and one point of the field. A bad illumination is so disastrous that, even at the present hour, many investigators are by no means convinced of the superiority of the apochromatic instrument. One cannot tell them often enough that this defect is solely due to the insufficiency of their condenser and to the poor choice of a luminous source. Achromatic, and even apochromatic condensers are in existence, and a *deplorable misjudgment* alone has prevented their general use.

Metallography.—In metallography the objective serves as condenser. The illumination thus obtained may be perfect (especially with apochromatics), but the lenses are more or less marked, which somewhat impairs their definition. In any case, it is the illumination which will have to be studied for improvements. The problem appears to be singularly arduous, and a long time will no doubt elapse before the introduction of notable perfections can be hoped for.

Conclusion.—In a general way mechanical perfections of the microscope will naturally result from progress in micrographic technics. From the optical point of view we are restricted, at least in usual practice, by the impossibility of going beyond the numerical aperture of 1.40. Better correction of the aberrations and especially of the field curvature seem only to be possible by the creation of new optical materials. Finally, the use of ultra-violet rays admits of increasing the definition to a considerable degree; but the insufficient transparency of the media frequently imposes a limit.

A NEW MICROSCOPE ILLUMINATOR.

By Alexander Silverman
(University of Pittsburgh, U.S.A.)

The device here described has already come into extensive use in the United States. The illuminator* and this paper are submitted for consideration by interested British societies.

The Lamp.—This consists of a quarter-inch glass tube containing a single tungsten filament. The tube is bent into a circle of one-inch inside diameter, and one and one-half inch outside diameter. It is made of colourless or blue (daylight) glass, and silvered, so that light is reflected downward from the circular source to the object being examined. The possibility of silvering the entire lamp and cutting a lateral line-slit in the mirror at the smallest diameter is under consideration to determine the possibility of producing through a plane of light a sort of ultra-microscope effect for the examination of bacteria.

The lamp is operated at 0.9 ampere and 13.5 volts for visual work, and 1.06 amperes and 18 volts for photographic work. Current from an ordinary lighting circuit is utilised, and controlled through a special rheostat (Fig. 1), which contains a push-button switch for the lower current and a spring-contact for the higher one.

The Holder.—An automatically adjustable support (Fig. 2), provided with three iris-like fingers, controlled by springs, is attached concentrically about the objective. The lamp is held to the underside of the support by two curved prongs and a perforated spring clip which slips over the exhaust protuberance of the lamp. The terminal wires from the lamp are attached to binding posts which are so constructed that they will also receive the brass pegs attached to the cord coming from the rheostat. These pegs may be inserted vertically or horizontally.

For general observation the lower portion of the lamp is in a plane with the flat face of the objective lens, but it may be raised or lowered to meet the needs of the operator.

Binocular Microscopes.—While the lamp-holder is clamped directly to the objective on monocular (Fig. 1), and single-objective binocular microscopes when 16 mm. or higher power objectives are employed, a stage support (Fig. 3) is provided for use with low power objectives and the Greenough binocular microscope. Lateral adjustment of the stage adapter centres the light and vertical

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* U.S. Patents 1,311,185, 1,311,186 and 1,257,287, British Patent 125,187, Canadian Patent 185,283, Italian Patent 48/485, French Patent 489,304. Other foreign patents pending.

adjustment enables the operator to keep the lamp at a constant distance from the object under examination.

The Shutter.—A shutter, which slips inside the lamp circle, may be placed under the lamp to cut off the light from one-half of the circle, so as to produce oblique illumination where this is desirable. Where depth without shadows is desired the shutter is unnecessary.

The Absorption Disc.—This is a dull black disc for covering highly polished surfaces, so that only the small portion under examination is exposed to the light.

Photomicrography.—For photomicrographic work the illuminator is attached as already described, and the camera employed without lenses, except those contained in the objective and ocular. For work done in this laboratory the camera shutter was left wide open. 16 and 32 mm. objectives were employed with a 10× ocular. As most microscopes are now equipped with vertical illuminators, the tube of such microscopes should be extended about 16 mm. when the vertical illuminator is removed and the new one attached. It is also desirable to use a Davis shutter in conjunction with the objective. Hammer ortho extra rapid plates were exposed for from 10 to 40 seconds, depending on the nature of the object photographed.

Low Power Work.—Excellent results have been obtained with low power objectives from 60 mm. to 16 mm. By using the stage adapter for 32 mm. and less powerful objectives, it is possible to place the lamp about one-quarter of an inch from the object and obtain beautiful effects. This is of advantage also with the double objective binocular microscope.

High Power Work.—The illuminator has proven satisfactory for oil-immersion work with a 1.8 mm. objective and 15× ocular (1,425 diameters). The markings on diatoms and structure of fine-grained alloys show clearly.

Heat of the Lamp.—To allay any fear concerning the heat radiated or conducted from the lamp, the writer begs to state that in his laboratory the lamp was attached to various objectives and run continuously at 100 per cent. over-voltage for more than half an hour without doing any harm to the objectives. Dr. E. M. Chamot, of Cornell University, conducted an independent series of experiments in which he drilled a hole in the side of the objective, inserting a small pyrometer tube between the lenses. He burned the lamp continuously over long periods, and pronounced it harmless.

Advantages.—The new illuminator, when used for the examination of opaque objects and others which may be viewed by reflected light, shows a greater wealth of detail than is obtainable by older methods.

It is of special value for examining objects which possess light-absorbing surfaces, invisible under vertical light, which are beautiful under the new light. This is easily verified by viewing papers, textiles, leaf rusts, insect wings, potato mould, etc.

In metals and alloys it shows the depth of penetration of the etching medium, contrast, colour, and as Director Stratton, of the U.S. Bureau of Standards, has pointed out, it enables one to see the slag content of pits which appear black under vertical light.

The new illuminator may be used without removing the vertical illuminator. By switching the respective lights on in turn, valuable comparative studies may be made.

The illuminator, when attached to the objective or to a special arm of the stage adapter, may be lowered into hollow objects, such as the steel test dishes used in the enamel industry, or vessels used for the study of pond life, etc.

The illuminator is attached to the microscope, which may be moved without throwing the light out of adjustment. In photographing it vibrates with the microscope should the latter be jarred.

The new illuminator eliminates eye strain. The intensity of light which reaches the eye is lower than that produced by other methods. There is no polished disc to interfere with the vision, and only rays reflected by the object examined strike the retina.

Acknowledgments.—The writer desires to express his appreciation of the generous co-operation of microscopists who have experimented with the new device. He desires especially to thank your Mr. S. C. Akehurst for the pleasure of his company and valuable suggestions made during his visit to the States, and for his kindness in presenting this paper before the members of your society.

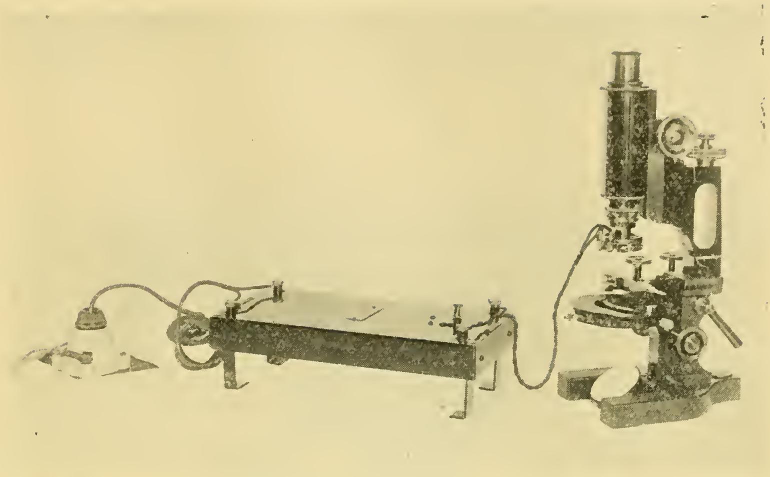

FIG 1.

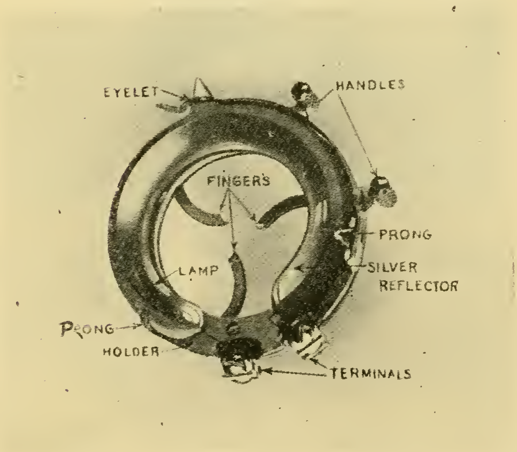
EYELET
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FIG. 2.

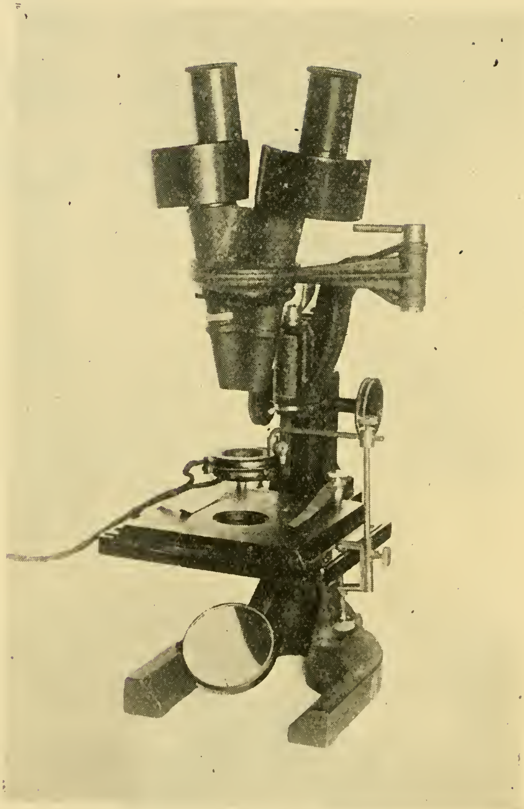


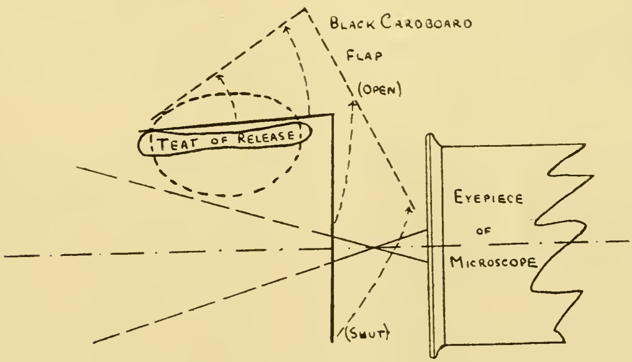
FIG. 3.

SOME PROBLEMS IN HIGH POWER PHOTOMICROGRAPHY.

By R. E. Slade, M.C., D.Sc., F.I.C., and G. I. Higson, M.Sc., A.I.C.

In an investigation of photographic emulsions we have found it necessary to take photomicrographs, using the greatest resolving power which we could obtain. In our attempts to overcome various difficulties inherent in different forms of apparatus, we have constructed an apparatus, which we believe contains some novel features.

The source of illumination is a 100 c.p. " Pointolite " lamp contained in a light tight box, a light tight connection being made between this box and the sub-stage condenser of the microscope, which is used in a horizontal position. Although this box is not ventilated we have not been troubled by heat from the lamp. No optical system or heat absorbing cell is interposed between the Pointolite lamp and the condenser, but an arrangement is fitted for introducing a colour screen in this position. The microscope is used with or without an eye-piece in



Action of Vibrationless Shutter.

a room which is totally dark, and the image is projected on to the plate, placed in a holder about one foot from the microscope, no camera being used. The whole apparatus is mounted on a solid block of ash. Focussing is done direct on to a piece of white card placed in the plate holder, a shutter is then brought down just in front of the eye-piece of the microscope, a plate put into the plate holder, and the exposure made.

This shutter, which is mounted quite separately from the base of the apparatus, consists of a roller blind shutter release, to the teat of which is attached a flap of black card (see Fig.), which is lifted clear of the path of the light rays by pressing the bulb of the release, exposure thus being made with complete absence of vibration.

In order to surmount the difficulty of imperfect achromatisation of the lenses, a green filter is used and photographs are taken on process plates sensitive to this light. In all apochromatic lenses there is always a good deal of curvature of field, and we should like to suggest that for photomicrographic purposes it would be useful to have a lens without any colour correction, if the elimination of other forms of aberration and curvature of field would be thereby facilitated.

The illumination used is always what is usually termed critical, that is to say, the light source is in focus on the plate at the same time as the object being photographed, this being rendered possible by the uniformity of illumination over the whole of the light source. In this connection we should like to put forward a theory of the well-known phenomenon of the flooding of light over the image at critical illumination when the aperture of the condenser is fully open. We believe that the explanation of at any rate a part of this is that the image of the light source which lies in the plane of the object is not an infinitely thin plane, and there is so little depth of focus with a high power objective that we have the effect of the image of a bright surface lying just in front or just behind the object and out of focus on the plate, producing the so-called flooding effect. If we cut down the aperture of the condenser we eventually use only light which is almost parallel, and therefore obtain a shadow photograph which is absolutely free from flooding. If we cut down the aperture only a small amount we may do so sufficiently to make the effect of flooding negligible. In support of this we may mention that flooding is not obtained if the image of the light source is very much out of focus. In the " Pointolite " lamp the curvature of the light source will contribute to this effect.

In some of our earlier work we used an achromatic lens between the " Pointolite " lamp and the condenser, but it was the light source which was always brought to a focus on the screen, and not the image of a diaphragm over the lens, as is sometimes done. This lens was used to magnify the image of the light source so that a larger part of the object could be illuminated, but the same effect is now secured by bringing the lamp as close as possible to the condenser. In this way we can illuminate an area of the object, which is a little larger than the flat part of the microscopic field. This increases the ease of aligning the optical system, and moreover slightly increases the working distance of the condenser, which, however, is never much more than 1 mm.

The exposure with the orthochromatic process plates in use, with the green filter and a magnification up to 2,000 diameters, varies from 2 to 10 seconds. In this connection it is important to note that for all work requiring the greatest resolution process plates (i.e., plates with a hard working emulsion*) must be used. (Goldberg, P. J., 52, 302 (1912).)

Laboratory of the British Photographic Research Association,
Chemical Department,
University College,
Gower Street.

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* In the December number of the *Photographic Journal* we have shown what type of emulsion is required to make a good process plate.

FATIGUE FACTORS INCIDENTAL IN THE USE OF CERTAIN OPTICAL INSTRUMENTS.

By Surgeon-Commander R. J. E. Hanson, O.B.E., M.A. (Cantab.), R.N.V.R.

Fatigue—when it exceeds physiological limits—is one of the most potent drawbacks to industrial efficiency.

Moreover, it is usually of no sudden onset after commencing the use of optical instrument or projection apparatus, but is rather the result of summation of effect.

The causation of undue fatigue may be summarized under three headings:—

Section 1.—*Faulty environment.*

(A) Mal Hygiene of the home.

(B) Mal Hygiene of the workshop.

(In connection with "A," the influence of day and continuation school conditions to be reckoned with.

Section 2.—*Defects in the Eye.*

(A) Extrinsic, *e.g.*, Heterophoria.

(B) Intrinsic, *e.g.*, Ametropia, etc.

Section 3.—*Central and Psychological.*

(Or a combination of any, or all, the above.)

The illuminating engineer is at work to secure good lighting conditions, with beneficial results in many directions. Of great importance also are satisfactory conditions of ventilation, temperature and hygrometry.

In this short communiqué, I desire particularly to consider defects in, or misuse of, the muscular mechanism of eye movement, resulting in mal-orientation of the eyes, *i.e.*, Section 2 (A).

In the use of the bioscope one has opportunity to study the fatigue resulting from flicker; excessive contrast (defective retinal adaptation);* inadequate stimulation of the retinal periphery, and disproportion between dimensions and illumination of screen picture and the distance therefrom of the seat occupied by the observer.

The distance between audience and picture screen should not be less than 3 × D (D = diagonal measurement of the picture).

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* The retinal periphery is best stimulated by means of clusters of frosted ruby (Fig. 1) coloured lamps suspended on brackets at intervals alongside the auditorium.

If an observer sits in the " auditorium " *below* the level of the centre of the pictorial field of action, he is soon fatigued, and brow-ache and discomfort ensue, for observation requires him to *extend* his head slightly from the " primary position," to raise his eyelids and rotate his eyes upwards.

If now he reseats himself at a higher level (" dress circle " angle), these factors disappear, for now his head is in the " primary position," or slightly *flexed*, a position assumed by gravitation and requiring very little muscular effort for its maintenance.

It has been suggested that the lower seats in a bioscope theatre should be tilted backwards with head rests, so that the necessary

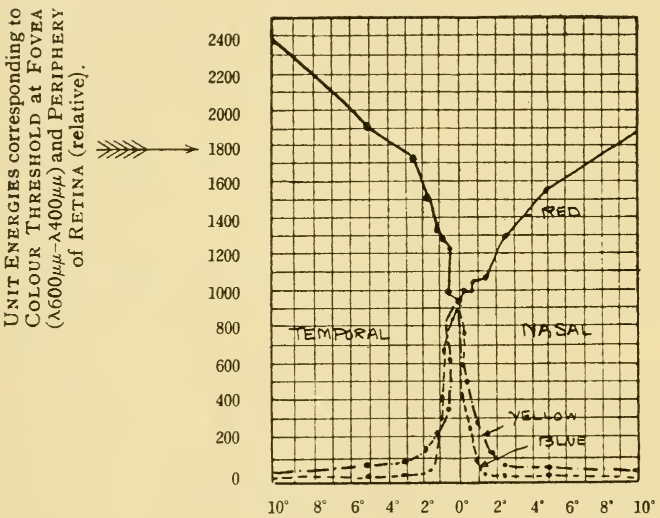

FIG. 1.

Diagram to indicate that the periphery of the retina is relatively less irritable to impact of radiant energy causing sensation of RED light, compared with the FOVEA (direct vision), observing that *the Adaptation phase* (*Dark or Light adapted*) *of the Retina does not affect the Red threshold.* The orange-yellow and blue (λ600-400) require the same number of energy units at their threshold of Perception, and are affected by the phase of adaptation of the Retina.

slightly extended position of the head may be attained without muscular effort and so avoid mal-orientation of the head and eyes. However, the promiscuous use of a head-rest in a place of public resort is not a feasible or pleasant proposition.

Fatigue factors, in connection with the observer's posture in using the *microscope*, are also present, and for him no facility is provided for resting his head and neck muscles, and insufficient attention is paid to the angle formed between the ocular and the vertical plane of the observer's head.

In order to avoid mal-orientation and resulting fatigue, it is necessary to provide the observer with a working bench of adequate height, correlated *height* and *position* of chair, suited to the physique of each observer.

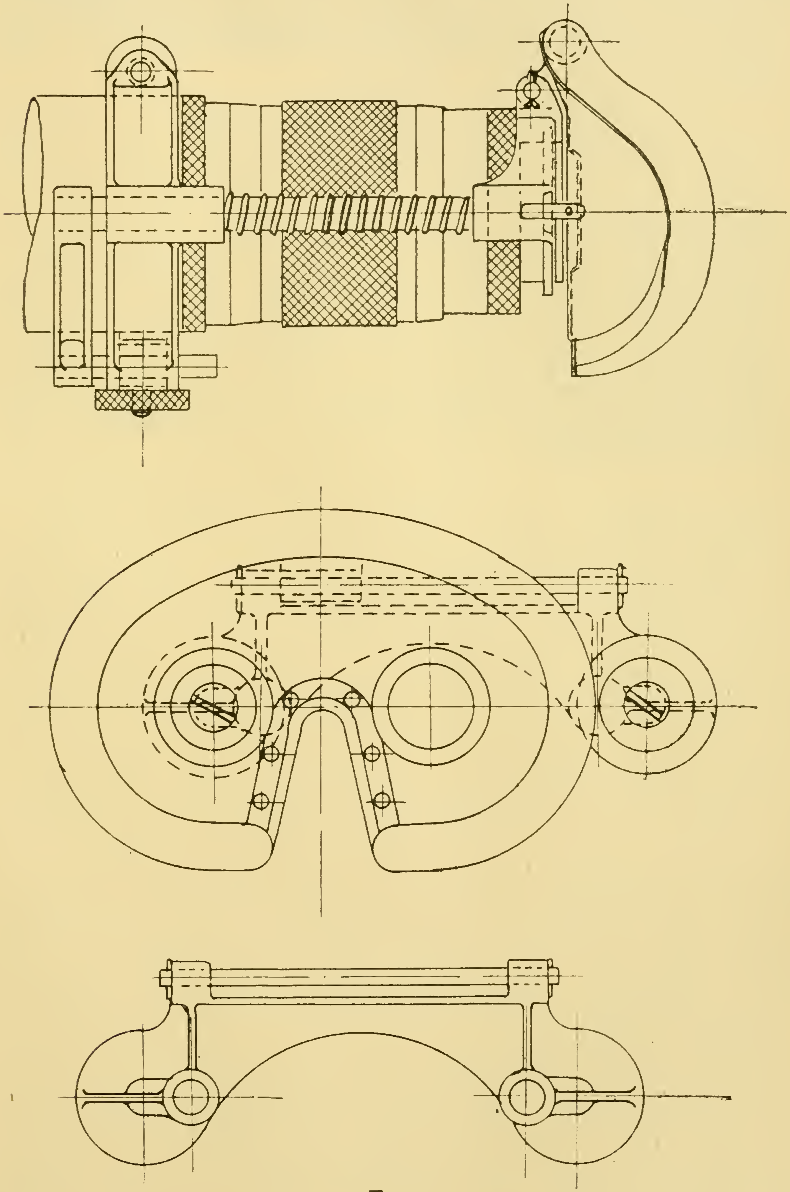

FIG. 2.

DYOPTIKON (PIVOTAL) HEAD-REST
(Universal Letters Patent).
Scale —One-Half.

I have put in as an exhibit a working model of a headpiece attachable to any standard tube microscope without necessitating any structural alteration in existing patterns, although it is intended to arrange a bracket with attachment at or below the trunnion, in any new pattern microscope available. Diagram and models illustrating application of this dyoptikon head-rest (eye-piece) to telescopes, etc., are also shown. (Fig. 2.)

I am also showing, by permission of Professor A. D. Waller, F.R.S., his early and original negatives showing the electrical response of retina to impacts of radiant energy of short duration; also solution of so-called "Visual purple" which exists in colloidal solution bathing the receptor organ (retinal cones and rods), a photochemical substance which under the above circumstances of external stimuli presents a balanced reversible reaction, and has been shown to flow into the central fovea where no rods exist. Its "sensitivity" is in accordance with Planck's minimum quantum of energy, and has been shown by Victor Henri to be several thousand times more sensitive to light than the most sensitive photographic plate, on rapid exposure. Spectroscopically, "Visual purple" shows *no absorption bands.*

A group of papers by **Dr. M. W. Travers, F.R.S., Dr. W. E. S. Turner, Mr. Robert Mond,** and **Mr. F. Twyman,** dealt with Optical Glass.

GLASS FOR OPTICAL PURPOSES.

By Morris W. Travers, D.Sc., F.R.S.

I have been associated with the glass industry since the outbreak of war, but the manufacture of optical glass in this country has been a matter of secrecy, and only officials have been admitted to the works, so that persons like myself can know only of what has been done indirectly and by rumour. British scientific literature contains one or two papers, indirectly connected with the subject, and the public and semi-scientific press contains only references to claims to discoveries of "German secrets" by British scientists—and denials that there were any secrets to discover. I hope that the claims are of a more substantial character than those put forward in connection with scientific glassware.

During the past autumn I made a tour of America, where I visited several of the new optical glass plants, to which I was freely admitted, and met many of the men who had been engaged in the development of the industry. During the early years of the war the manufacture of optical glass had been carried on in a rather desultory fashion, but in April, 1917, American industry was suddenly called upon to meet an enormous demand for optical glass. It might have been thought that America would have made use of the information gathered in this country, but an American scientist who took a leading part in developing the industry told me that this was not the case, for "we understood that your Government had a lot of information on the subject of optical glass, but we could get nothing out of them at all."

America was, however, in a very advantageous position from which to attack the problem. In the first place there were ample funds for research, administered by a thoroughly scientific body, the National Research Council, and not by a Government Department, scientific only in name. In the second place there already existed the organisation of the Geophysical Laboratory of the Carnegie Institution. Of the work of this institution the Report of the Director for the year 1918 speaks as follows:—"Suffice it to say that with a group of 20 scientifically trained men, all trained in handling silicate solutions at temperatures required for the making of glass, and familiar with the control of most of the important factors in the problem, it proved practicable to make rapid progress, and in June following, after two months of concentrated effort, the gross production of glass by a leading manufacturing firm had increased from 15,000 to 28,000 pounds per month, and in quality had improved to such an extent that rejections by Government inspectors became comparatively rare." The results are really expressed in the last sixteen words of the quotation.

The rapid progress made in America was largely due to the fact that the scientists of the Geophysical Laboratory, and of the Bureau of Standards, were not content to sit on High Olympus in the suburbs of Washington, but did their work in the manufacturing plants, from which the results of their researches are issued. Thus science and industry co-operated in the closest possible manner, with results which speak for themselves; for not only were the practical results aimed at actually achieved, but a very large volume of scientific research was carried out, much of which has already been published in American scientific literature, while much more awaits publication.

We have certainly done good practical work in a limited field in this country, and nothing pleased me more than to hear the quality of some of our British scientific glass praised in America. The greater credit to those to whom the results are due, who have worked, as Englishmen often work best, in face of difficulties. Given the opportunity, the British scientist is equal to any in knowledge, and superior to most in grit; but the policy adopted by our Government Departments of attempting to monopolise science, and draw a dividing line between science in the university laboratory and science in the works, is fatal both to scientific and industrial progress.

GLASS FOR OPTICAL PURPOSES.

By W. E. S. Turner, D.Sc., M.Sc.,

Of the Department of Glass Technology, Sheffield University.

It is with great reluctance that I find I must forgo the pleasure of being present at the Symposium on Wednesday next.

I am glad to know that some members of the Society of Glass Technology will be present and take part in the proceedings. The fine array of papers is a tribute to the great efforts Sir Robert Hadfield has made to direct the attention of scientific men to the importance of encouraging the production of all-British optical instruments.

Amongst the large number of papers, however, I do not find a single one dealing with the manufacture of optical glass. It is, in my opinion, unfortunate that there should not be as free and ready a discussion of this subject as had taken place in America in these past three years.

I should like to make some remarks of a very general character to indicate to makers and users of instruments the position in which optical glass makers frequently find themselves. There is, in my mind, not the slightest doubt that we can produce in this country all the types of glass requisite for microscopes and other optical instruments. The long experience of Messrs. Chance Bros., and the splendid achievements of the new Derby Crown Glass Co. undoubtedly demonstate this.

The amount of optical glass in any one instrument is, as a rule, quite small, whilst for the instruments of high precision, even the total amount of glass called for by manufacturers is very small. The glass maker, however, knows that in order to ensure homogeneity, freedom from striae, etc., from the glass, he must make a melt on a considerable scale. Further, some designers of optical instruments will call for a new glass of special properties, may be, for example, one which is successful in eliminating light rays between certain wave-lengths. The production of such a glass calls for considerable research on the part of the glass manufacturer, and he usually cannot expect to sell but a very small quantity when produced, whilst the instrument maker is not prepared to cover the cost. Such a demand cannot always be met by the glass manufacturer; it is in no sense a commercial proposition. For some reason, connected probably with the early days of German competition, the manufacture even of the well-known varieties of optical glass has never been remunerative, although with the recent American products the prices, I believe, have had a more reasonable relation to the cost. One American manufacturer stated that he was prepared to continue the manufacture of optical glass if the loss was not greater than 10,000 dollars per annum, although he was hoping, eventually, the factory costs might be balanced by income.

There is an obvious remedy for the unremunerative rates for optical glass, namely, that instrument makers should be prepared to pay prices sufficient to make the industry financially sound. There is also a means by which special glasses, required only in small quantities, may be made without asking glass manufacturers to go to unnecessary trouble and expense. It lies in the use of the joint resources of the laboratories of the British Optical Instrument Manufacturers' Research Association, under Sir Herbert Jackson, and of the Department of Glass Technology in the University of Sheffield.

The last-named Institution has been equipped in such a manner as to be admirably adapted for making special glasses in smaller quantities than the manufacturer can consider worth while, and meltings up to two cwt. in size can be undertaken. Where it is a matter of importance that a special glass shall be worked out, I urge most strongly that the joint resources of the two laboratories be employed.

In regard to crystals of calcium fluoride, I heartily concur with Sir Robert Hadfield's views that it would be strange if the mineral resources of the Empire could not furnish our requirements. Some time ago I received from a merchant, Mr. B. Moss, 21, King Street, Covent Garden, London, W.C., a beautiful specimen of crystalline calcium fluoride from a mine in the neighbourhood of Johannesburg. I am forwarding specimens of this to you. When I say that the specimen was sent with the object of obtaining a market amongst manufacturers of common glass articles only, it will be agreed that the source may be worth further exploitation for optical specimens.

The manufacture of optical glass in America, taken up only during the war, is still a long way behind ours in output and variety. Recently I was able to visit practically all of the war plants. The number of types of glass made so far is limited, and in the last few months all the plants except that of the Spencer Lens Co., at Hamburg, New York, and the new experimental plant at the Bureau of Standards, Washington, have closed down. For a long time, therefore, there should be in America an important market for optical glass made in this country.

NOTE ON FLUORITE.

By Robert L. Mond.

Our Chairman, Sir Robert Hadfield, has asked me to ascertain whether crystals of fluorite suitable for optical purposes, of which there is a great shortage, are obtainable in the Dominion of Canada.

I at once got into communication with my friend, Mr. C. V. Corless, the General Manager of our nickel mines in Canada, who succeeded in ascertaining for me the following facts.

Crystallised fluorite is exceedingly scarce in Canadian deposits, and there only appears to be one property of any promise in Canada. Mr. Gavin M. Wallbridge, owner of the Wallbridge Mine, Madoc, Ontario, has sent me one crystal, which I herewith submit. In this mine there are two veins, which contain some beautiful, pure white crystals; he has supplied some of these crystals to Messrs. Bausch and Lomb, of New York. The crystal he has sent me he states to be from the second vein. This property is flooded at the present moment, and he cannot work it until next Spring. If material slightly off colour would be suitable, he would be in a position to supply straight away, but the clear white he could not supply before next Spring.

The vein is a closely packed one, tight from wall to wall, and in using dynamite to loosen the ore, all the crystals within a few feet of the shot hole are shattered. He is sometimes able, however, to locate a rough hole after mucking operations, and with great care and a lot of time he is able to save some beautiful specimens. He continues to state that the price which he obtained last year was so much less than the value stated by the Bulletin issued in Washington that he became disgusted, and did not bother to make any attempt to save the crystals.

He further states that he has not an expert there to place a value on the crystals, and, in consequence, must trust to the business honesty of the consignee. He has no doubt that a British firm would "play the game." He is much interested in the crystals end of the business, and would be very pleased to hear if the slightly off-coloured crystals would be of any use, and what would be the smallest size worth submitting.

I am also in receipt of a letter from Mr. Thos. Gibson, Deputy Minister of Mines, who has interviewed the brother of Mr. Wallbridge. He informs us that the deposit is very limited, and that the deposit not now being worked was much more promising. Mr. Gibson's impression is that we cannot count upon the Madoc Mine furnishing any commercial supply of the special type of fluorite, unless the demand is extremely small.

The material is undoubtedly fluorite, and I have submitted the sample to Messrs. Swift and Sons, who propose cutting a lens or prism from it to ascertain its optical properties.

Although the actual specimen is a large crystal, there are only relatively small portions of it which appear to me suitable for optical use. As this crystal was sent to me from Canada in a canvas bag, it may have suffered crushing in transit.

I regret I have not been more successful in obtaining information as regards the occurrence of this mineral.

THE ANNEALING OF GLASS.

By F. Twyman.

Although owing to the small sizes of microscope lenses, and the fact that they are usually cut out of comparatively massive pieces of glass, want of annealing is very unlikely to cause the microscope maker any trouble, yet a few remarks relative to the principles underlying the annealing of optical glass may be of interest, if for no other reason than that the same principles underlie the efficient moulding of glass (or indeed of other materials), and there is no reason why an appreciable saving in the cost of manufacture of microscope objectives might not be effected by high quality moulding.

When the Research Laboratory of Adam Hilger, Limited, took up the question of annealing glass in 1915, we were unable to discover that any research work of a fundamental character had been done on the subject. We were unable to find even a clear presentation of the cause of faulty annealing. For various reasons we have not published a full account of the work, but the principles involved and some of the results as applied to glassware will be found sufficiently fully described in a paper read before the Society of Glass Technology in 1917. ("The Annealing of Glass," by F. Twyman. *Trans. Soc. Glass Technology*, 1917. I. 61, *et seq.*)

The phrase "badly annealed" when applied to glassware implies the presence of internal stress.

When glass is in a definitely molten condition there can be, of course, no permanent internal stress. Moreover, it can be shown, by keeping a suitable glass object under observation in a tube furnace, that even when the glass is cool enough to be practically solid under such stresses as are occasioned by its own weight, it may yet be mobile enough for severe internal stresses to disappear in a few minutes. On the other hand, at ordinary air temperatures glass is almost (though not quite) perfectly elastic.

But between this high temperature, where the glass is so mobile that internal stresses are evanescent in, at most, a few seconds, and the low temperatures, where the glass behaves as an elastic solid, is a region where internal stresses take, say, a minute, or an hour, or a few hours, to die out. It is this range of temperature which is important in annealing, and an accurate knowledge of the mechanical properties of the glass throughout this region is necessary if we are to attain any specified perfection of annealing in a minimum time, and without distortion of the articles. This region I call the annealing range.

If it were possible to cool any glass object from the high temperature down to ordinary air temperature in such a way that the temperature remained uniform throughout the mass, then no matter how fast the cooling the glass would be well annealed.

What actually happens is that differences of temperature exist while the glass is cooling. The stresses so caused are transient, so long as the glass is within the annealing range; but when eventually it becomes cold and the temperature uniform, there are present permanent stresses depending on the variations of temperature throughout the mass which existed while the glass was cooling.

To anneal glass, then, it is necessary to keep it within the annealing range till the stresses have died out, and then to cool it with sufficient slowness. No kind of heat treatment which does not raise a badly annealed sample of glass to within this range will greatly affect its condition of internal stress, whether for good or ill, in any reasonable time.

The method developed in our laboratory for determining the annealing temperature will be found in the paper cited above. The steps in the argument may be briefly summarised.

The degree of annealing to be attained, and the time in which it is to be accomplished must be defined. For glassware we have laid down the condition that at the annealing temperature 95 per cent. of the original stress must disappear in three minutes. For optical glass appropriately modified stipulations are adopted.

The case of the disappearance of stress in a viscous body was considered by Maxwell,* who gave an exponential expression applicable to such cases connecting stress with time, thus

$$F = ESe^{-\frac{t}{T}}$$

where S is a distortion or strain of some kind produced in the body by displacement, F is the stress thus excited, E is the co-efficient of elasticity for that particular kind of strain, t the time, and T a time named by Maxwell the time of relaxation, which depends on the nature of the body.

The product ET he calls the co-efficient of viscosity, since in the case of steady progressive strain or distortion produced by constant stress the rate of strain multiplied by this product gives the stress.

It is obvious, then, that by defining the annealing temperature in the way we do, we have at the same time defined a viscosity. All we have to do, then, is to find the temperature at which the glass has the viscosity so defined, and we have the annealing temperature.

For details of apparatus and method the paper mentioned above must be referred to; but one point may be of interest.

It was found by us that in the neighbourhood of the annealing range most glasses examined double in mobility for every 8° C. rise of temperature, approximately. If then an attempt were made to anneal at 500° C. a glass whose annealing temperature (as defined above) is 580° C., the glass would require to be left one thousand times as long in the former case as in the latter.

The Research Laboratory,
Adam Hilger, Ltd.

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* Phil. Mag. S 4, Vol. 35, Feb., 1868, p. 129.

APPLICATIONS OF THE MICROSCOPE.

The following papers and communications dealt with recent developments in the applications of the microscope, particularly in industry.

This portion of the Symposium was introduced by the presentation of a paper on "The Great Work of Sorby," by **Sir Robert Hadfield, Bart., F.R.S.**

THE GREAT WORK OF SORBY.

By the President of the Faraday Society

(Sir Robert Hadfield, Bart., D.Sc., D.Met., F.R.S.).

Early Work; Researches on Metals; Researches on Rock Sections; Work on Meteorites; Application of Sorby's Work to Metallurgy.

In the First Sorby Lecture "On Some Structural Analogies between Igneous Rocks and Metals," read before the Sheffield Society of Engineers and Metallurgists in February, 1914, Professor W. G. Fearnsides, M.A., F.G.S., rightly said that the audience had met together to honour the father of Modern Petrography, that citizen of Sheffield, Henry Clifton Sorby. Professor Fearnsides has dealt with the subject in such an excellent manner and given so much valuable information in his lecture that I quote him very fully.

Early Work.—Sorby's earliest Research Work was in 1849 when he prepared the first rock slice ever made, and his first microscopical study of igneous rocks was presented in his historic Paper read before the Geological Society of London on December 2nd, 1857. His attempts were received almost with derision, some of the Members present saying that he was drawing largely on their credulity. Later he was thoroughly avenged by the Geologists of all Nations who assembled to celebrate the Centenary of the Geological Society of London when Sorby on the results which were formerly derided was acknowledged and acclaimed by them to be the founder of modern Petrography.

Researches on Metals.—Sorby began his work on Metals in 1863 and lectured about it in Sheffield before the Literary and Philosophical Society in February, 1864 ("On a New Method of Illustrating the Structure of Various Kinds of 'Blister Steel' by Nature Printing," Sheffield Lit. & Phil. Soc., 1864). Unfortunately there is no trace of this in the Proceedings. My own impression is that this Paper was

one which was read before the National Science Section of that Society, but no copy was kept of it. When residing chiefly in Sheffield I was a Member of this Section, often meeting Dr. Sorby there. It is now no longer in existence.

Later on Sorby communicated his results at the Bath Meeting of the British Association ("On Microscopical Photographs of Various kinds of Iron and Steel," B.A. Report, 1864, Pt. II, page 189). In this Paper the Author briefly explained how sections of Iron and Steel might be prepared for the Microscope so as to exhibit their structure to a perfection that left little to be desired. He also exhibited a series of photographs taken by Mr. Charles Hoole illustrating the various stages in the manufacture of Iron and Steel and describing the structures which they presented. They showed various mixtures of Iron, of two or three well-defined compounds of Iron and Carbon, of Graphite, and of Slag; and these, being present in different proportions and arranged in various manners, gave rise to a large number of varieties of Iron and Steel differing by well-marked and very striking peculiarities of structure.

For 22 years the observations attracted little or no attention and when in 1877 Professor Martens, Berlin, and later M. Osmond and M. Le Chatelier, Paris, began to study metals with the Microscope they had to develop independently and anew the craft which Sorby had invented many years before. Sorby lectured on "The Microscopical Structure of Iron and Steel" at Firth College, Sheffield, in October, 1882, and stated that in view of the knowledge of fresh facts he had re-examined the whole of his specimens with improved Apparatus. In 1885 by the use of Lenses of high resolving power and large magnification he first discovered the true composite nature of the "Pearly Constituent" of steel as an aggregate of parallel plates, which discovery may be reckoned the crowning achievement of his microscopical research. Sorby announced this discovery to the Iron and Steel Institute in 1886, "On the Application of Very High Powers to the Study of Microscopical Structure of Steel," Journal of the Iron and Steel Institute, Vol. I, 1886, pages 140 to 144. Subsequently he presented to the same Institution his great Paper "The Microscopical Structure of Iron and Steel," giving a full account of his methods and the results he had obtained. (Journal I.S.I., Vol. I, 1887, pages 255 to 288). These Papers proved to be the signal for great activity in the field which he had so brilliantly started to explore, but it was really far back in the 'sixties that Sorby originated the Science of Metallography. His work at this period gave cause for an American writer in 1900 to say of him (in the "Metallographist" of April, 1900, Boston, U.S.A.): "Whatever has been accomplished since in microscopic metallography has been done by following in his footsteps. To Dr. Sorby and to him alone is due the pioneer's honour."

Researches on Rock Sections.—At the period (1849) when Sorby began his researches on rocks, the only available knowledge of the constitution of igneous rocks was that gained either by the field-worker with his hammer or by the indoor Geologist by the tedious processes of chemical analysis. Slices of rock

ground to a thinness of about one-thousandth of an inch allowed light to pass, and with the Microscope it became possible to see their structure more clearly than the texture of the coarsest granite had hitherto appeared. Rock-slices, having been ground down flat, were admirably adapted to the application of polarized light, and to one who had already a working knowledge of optics, the vagaries of the vector variations of the optical properties of minerals proved to be no deterrent. Finding no treatise on this subject ready-made, Sorby designed, and, with his own hands constructed, a polariscope to work either with parallel or with convergent light, and the very instrument which he then made is still in use in the Sheffield University Physical Laboratory.

Researches on Meteorites.—Subsequent to his early Petrological Researches, Sorby turned his attention to the Microscopical Study of Meteorites.

In his Paper "On the Microscopical Structure of Meteorites" (Royal Society Proceedings, 1864, p. 333) he pointed out that he had applied to the Study of Meteorites the principles he had made use of in the investigation of terrestrial rocks described in his various Papers and specially in that on the Microscopical Structure of Crystals (Quarterly Jnl. Geol. Soc. 1858, Vol. XIV, p. 453). He there showed that the presence in Crystals of "fluid, glass, stone, or gas cavities" enabled the conditions under which the crystals were formed to be satisfactorily determined. There were also other methods of enquiry still requiring much investigation and a number of experiments to be made, but not wishing to postpone the publication of certain facts he gave a short account of them in this Paper.

This Paper was followed by another "On the conclusion to be drawn from the Physical Structure of some Meteorites" (B.A. Report, 1864, p. 70), in which Sorby pointed out that he had previously shown that the earliest condition of meteorites of which their microscopical structure furnishes evidence was that of igneous fusion. There were, however, some, like the Pallas Iron, consisting of a mixture of Iron and Olivine which apparently strongly opposed this view if judged from what occurred when melted artificially; for then the Iron being so much more dense would sink to the bottom and the Olivine rise to the top like slag in a furnace. The object of this Paper was however to show that this difference in density depended on the force of gravitation and that, on the surface of a small planetary body, or towards the interior of a larger planetary body, Iron and Olivine might remain mixed in a state of fusion long enough to allow of gradual crystallisation. Such meteorites should therefore be considered evidence of fusion where the force of gravitation was very small; and this conclusion might be valuable in deciding between rival theories of their origin.

Application of Sorby's Work to Metallurgy.—At the time these researches were carried out, although the Science of Metallurgy had advanced at a great rate, Chemical analysis remained the ultimate arbiter of the quality of any metal. The work, however, of Gore,

Barrett and Tchernoff on the intimate relationship existing between recalescence and the hardening of steel, and also the work of Guthrie on eutectics led to the idea that both igneous rocks and alloyed metal are the products of the crystallisation of mixed solutions. Bunsen, and subsequently Vogt of Christiania, called attention to the laws which control the crystallisation of minerals in slag, and when Teall in 1888 pointed out the similarities of structure between graphic intergrowths and Guthrie's eutexia of Metals, the application of the solution hypothesis to rocks became apparent. In the domain of Metallurgy, the introduction of the Thermocouple by Professor le Chatelier led to the study of the Thermal Changes which accompany physical or chemical variations of constitution within the metal.

Sorby, in his Paper contributed to the Iron and Steel Institute in 1887 and published in Vol. I of the Journal for that year, stated:

"It is now twenty years since I commenced to carefully study the microscopic structure of Iron and Steel. The first object was the study of meteoric iron, but I soon found that the results were of even more value in connection with practical metallurgy."

Again, on page 276 of the same volume, he says:

"I regard that even a power of 400 linear fails to show whether the pearly constituent remains unaltered or broke up into very fine laminæ when very suddenly cooled. It either does not or the laminæ are too thin to be recognised. The changes in structure produced by hardening deserve far more study, but will I fear tax to the utmost the capabilities of the Microscope since the constituent grains of hardened steel are so extremely minute."

At this stage Sorby's work on Metals received recognition and exerted a powerful influence. It became evident that the mechanical properties of Iron and Steel depend upon the properties of their crystalline constituents, and at this period the nomenclature of metallography was developed. The subsequent work of Raoult, Van't Hoff, Gibbs, etc., led to a tendency to decry the nomenclature as unscientific. Nevertheless, it is still used and serves well for the ready specification of different qualities of steel.

Professor Judd, who was a friend of Sorby, has given some interesting reminiscences of the conditions under which Sorby worked. Apropos of Sorby's Laboratory, he remarked: "You speak of Sorby's laboratory. All his work, when I knew him, was done in a private room in his house; there everything was as simple as Wollaston's—a table with his Microscope, and a few bits of apparatus lying about."

In the same connection, Judd also remarked: "I went to Sheffield, as a Chemist to the Cyclops Works, straight from the Jermyn Street School of Mines in the Summer of 1864, and at once met Sorby. He not only taught me to make rock-sections, but showed me what he was doing with artificial irons—led to it by his studies of iron-meteorites. Mr. George Wilson, then manager of Cammells, a very enlightened man, gave me permission to supply Sorby with any irons that I analysed, for his work, so that I saw the beginning of his Metallurgical work—a very pleasant reminiscence. Down to the time that Ward

and I left the Geological Survey, in 1871, Microscopic Petrography was always ridiculed by 'the powers that were.' They always said, 'You can't study mountains through Microscopes.'"

The following appreciation of Sorby's work is made by M. Ch. Frémont, the well-known French Engineer and Metallurgist:—

"It was Sorby's discovery of the method whereby the structure of a metal was laid bare to microscopic examination that gave him the right to the title. The method he used to prepare his rock sections failed him with metals, because the latter, even in very thin sections, are not transparent. Sorby, however, discovered that by suitably etching a perfectly polished surface of metal the structure was revealed to microscopic examination." The great merit of Sorby consisted in having applied to Metallurgy the Micrographic method he had discovered and introduced in the study of Mineralogy.

Our Meeting this evening is a living evidence of "Great is the Truth and it will Prevail." From the humblest of beginnings this method of research has grown into a giant. It will still further help to add to the sum total of human knowledge from which all may benefit. All honour to this Great Englishman for the magnificent work he accomplished.

THE REQUIREMENTS OF THE PETROLOGICAL MICROSCOPE.

By Dr. J. W. Evans, F.R.S.

The Petrological microscope is constructed to serve two purposes. It is employed, in the first place, as an ordinary microscope, to observe the form and structure of the smaller features of rocks; and it is also used as an optical instrument for studying the action of minute crystals on light with a view to their identification. The latter function requires special features of greater or less complexity. The exact nature of these arrangements depends, however, to some extent on whether the material is examined in the form of a thin section of a rock, or in minute grains or fragments.

In all petrological microscopes provision is made for the examination of the object between crossed nicols, and for the rotation of these or of the stage or of both alternatively. The advantage of a rotating stage and stationary nicols is so great from the point of view of simplicity of construction, that it is always adopted in the cheaper instruments, and it is quite satisfactory in all cases where the work is confined to thin sections and methods involving certain special accessories or arrangements are not required to be employed.

On the other hand, for the examination of grains mounted in oil or other highly refracting medium, the use of a stationary stage and rotating nicols is practically a necessity, if high powers are to be employed, unless the Nachet device is adopted, by which the objective is attached to the stage and rotates with it. Rotating nicols are also necessary for the more complex optical methods, especially those that require an axis of rotation at right angles to the optical axis of the microscope, as when the optical characters of crystals are studied by means of the theodolite or " universal " stage. It deserves consideration whether, when rotating nicols are employed, a rigid connection between them should not be substituted for the gearing employed by Dick, even although the former is open to the objection that a rotation through a complete circle is not possible. This course has been occasionally followed.

Where crushed material or small grains are examined in oil or micro-chemical tests are applied, the microscope should be protected by a shallow glass bath with a plane floor, large enough to hold the glass slip.

There should be a " mechanical stage " providing for the movement of the object in two directions at right angles to each other and to the optic axis of the microscope, so that the position of the object may be varied while its orientation remains unaltered. These movements and the fine adjustment should be accurately graduated.

Arrangements should also be made by which a nicol may be placed in a position above the eye-piece. At the same time a slot should be provided at the focus of the eye-piece, so that accessories, such as quartz wedges, may be inserted in focus. The upper nicol or analyser, wherever placed, should be capable of rotation, either simul-

taneously with the lower nicol or polariser or independently of it, and there should be special facilities for adjusting it at small angles of divergence from 3 to 6 degrees from the position of crossed nicols.* This is useful in determining the exact position of extinction.

Greater facilities should be given for the study of the interference figures in the "directions image" in polarised light. It is difficult to exaggerate the value of the purely qualitative results described by Beck, as well as the quantitative methods which involve careful measurements of the "isogyres" or dark bars.† For these purposes immersion objectives with an especially wide angle should be used with highly refracting liquids, and a corresponding wide-angled illumination should be provided. It is absolutely necessary that the student should be in a position to isolate the light from minute crystals surrounded by others of different composition or with different orientation. Among othr examples may be mentioned the zones and twin lamellae of plagioclase. By far the best means of effecting this is by inserting a diaphragm in the focus of the eye-piece and a Becke lens placed above it.‡ This should be a recognised accessory with all except the most elementary petrological microscopes. Provision should be made to enable the exact course of the isogyres to be measured. There is no space here to discuss the merits of the different devices which have been suggested, including one for which I am responsible.§

Some arrangements should also be available for the study of the object in linear convergent light, which is advantageous for various purposes. It can be obtained by employing an ordinary convergent system and inserting a narrow slit in a focus conjugate to infinity, with such orientation relatively to the object as may be required.||

Provision should also be made for the use of monochromatic light when desired. The slit already referred to may be employed for the purpose in conjunction with a prism; or some form of monochromator, or a colour screen may be substituted, unless coloured flames be preferred.

I have not attempted to deal with all the numerous accessories which have been employed or suggested in petrological work, but have confined myself mainly to variations of construction necessitated by special methods.

Reference may be made to the report of the Microscope Committee of the British Science Guild giving a specification of a student's petrological microscope.¶

A serious difficulty is presented by the high cost of petrological microscopes constructed so as to allow of the application of advanced methods of research. This is inevitable so long as the number of instruments manufactured is too small to justify the employment of systematic standardisation with interchangeable parts.

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* F. E. Wright, Am. Journ. Sci., Vol. 26., pp. 349-368, 380-386 (1908).

† Min. Mag., Vol. XIV, pp. 230-234, 276-281 (1907); Min. Patr. Mitt., Vol. XXIV, pp. 1-34 (1905).

‡ Min. Mag., Vol. XVIII, pp. 45-51 (1916).

§ Mineralogical Magazine, Vol. XVIII, pp. 52-57 (1916).

|| Min. Mag., Vol. XVIII, pp. 130-132 (1917).

¶ Journ. Brit. Sci. Guild; November, 1916, pp. 28-31.

There are two directions in which we may look for an increase in the demand for instruments of this type. The first is the general adoption by chemists of optical methods of studying crystalline chemical products, and the second, the stimulation of the demand for British instruments in other countries. Every encouragement should be given to those engaged in original scientific work to design new or improved types of microscopes or accessories, and each new type should be fully described in the scientific and technical journals by the inventor, whether he is a member of the staff of a University or of that of an optical factory. If this policy is effectively pursued, other countries will turn to British makers for the supply of instruments of the latest and most novel patterns.

It was by such methods that the well-known German makers obtained the commanding position they held before the war, and it is only on these lines that our country can hope to take the place that it ought to have in the manufacture of specialised types of microscopes.

The working out of new ideas involves, however, considerable expense, far greater than is afterwards required to construct similar instruments when standardised and produced on a large scale, and it is absolutely necessary that pecuniary assistance should be, in the first place, forthcoming, if success is to be ultimately achieved.

APPLICATION OF THE MICROSCOPE TO THE SELECTION AND CONTROL OF YEAST EMPLOYED FOR BREWING PURPOSES.

By A. Chaston Chapman.

The application of the microscope to the selection and control of yeast in the brewery may be said to date from the publication in 1876 of Pasteur's "Etudes sur la Biere." In this he made his famous pronouncements "That every unhealthy change in the quality of beers coincides with the development of micro-organisms foreign to brewer's yeast properly so-called," and that "the absence of change in wort and beer coincides with the absence of foreign micro-organisms."

By "foreign micro-organisms" in the above statements Pasteur referred solely to bacteria, and it was some years later (1879) that Hansen outlined his method of making pure cultures of yeast starting from a single cell. As a result of the application of this method, he showed that some of the yeast species which were frequently present, both in the pitching yeast of the brewery and in the air, were capable of producing "diseases" in beer quite as serious as those produced by bacteria. By a study of ascospore formation and other biological characters of the various species, it was found possible to make a distinction between the culture yeasts and the so-called "wild" yeasts sufficiently definite to enable one cell of the latter to be detected in the presence of at least 100 cells of culture yeast. By means of the microscope, therefore, it is possible to detect the contamination of the pitching yeast, not only with bacteria, but also with other undesirable yeast species, and to take the necessary steps to purify it.

Lantern slides representing culture yeasts and a number of the "wild" yeasts in illustration of the above statements were shown.

THE MICROSCOPIC OUTFIT OF A TEXTILE RESEARCH LABORATORY.

By R. S. Willows, M.A., D.Sc.

In the interests of brevity I will confine my remarks closely to the requirements of a research worker in the textile industry. The materials to be examined are fabrics, yarns, fibres, starches, and

Objectives.

The objectives used will be from 2 in. down to an oil immersion, and for certain purposes an ultra-microscope of the cardioid or similar type, while for special work an immersion ultra-microscope may be a great advantage. The most useful lenses are the 16 mm., the 6 mm., and in a less degree the 4 mm. and an oil immersion. The first is most useful for examining single fibres, while the second will do most of the routine work on sections, especially if it will stand a high power eye-piece. Strange to say, at least one English maker of high-class lenses does not produce a 6 mm. lens. I have found certain English apochromats excellent in flatness of field and definition, but they have the disadvantage of a short working distance; it is fair to add that in the last respect they are no worse than Continental types. For most purposes I find some semi-apochromats in my possession are all that is required; the field is not very flat, but the definition in the centre is excellent, their working distance is large, they will stand an $\times 18$ eye-piece, and they are comparatively inexpensive.

Stands.

I prefer the English type of stand to the Continental model, on account of the better distribution of weight and consequent greater stability, and also for the greater space for the substage. The tube must rack out to take a 2 in. objective, and in this connection it is a great advantage if the stage can also be racked. The latter movement is also very useful when it is required to use vertical illumination. A mechanical stage, centering substage, and high-class condenser are taken for granted, even on the simplest types of stand. Very frequently a considerable portion of the slide has to be examined; this should be possible without fouling the condenser.

As the material to be examined has frequently to be submitted to the action of acids and alkalis while it is on the stage, the latter should be made of a suitable material, and should be designed so as to eliminate as far as possible the chance of injury to the instrument. Apart from material used, the design of such a stage appears to have received little attention. It is in such examinations that a large working distance for the objective is so markedly advantageous.

Polarisation Apparatus.

This is often extremely crude. Types which require the analyser to be screwed on behind the objective, or in which the polariser replaces the condenser, not only waste much time in making the necessary changes, but the illumination is cut down badly. The analyser should be built in the body tube, should be capable of being swung or slid out when not required, and the analyser should come below the condenser and should have the swing-out motion.

Ultra-microscope.

An efficient and easily handled form of ultra-microscope is urgently required, not only for general scientific research, but also in several branches of textile work, especially on the sizes and dyes.

Photomicrographic Apparatus.

It is on this side that English apparatus is most defective. Where it is not a frank imitation of foreign types, it shows no evidence of design as a whole, and in a number of small details is so defective that I sometimes doubt if its makers have ever used it to take photographs under the varied conditions that exist in a works research laboratory. For my own purposes I desire an equipment fulfilling the following conditions:—

(1) As it will be used where there is considerable vibration, the mechanical design should be such as to reduce the effects of this vibration to a minimum. That eliminates the type where camera and microscope are on separate stands.

(2) It should be easy to make a visual examination before the photograph is taken. This is most readily done by swinging the optical system and microscope out of line with the camera. It may be difficult when the light source is a large arc surrounded by a lantern, but is comparatively easy if a "Pointolite" set is used. I have found this source most efficient and handy. It consists, as is well known, of a tungsten arc in nitrogen; it burns for hours without the slightest attention, and as the spectrum of tungsten is exceptionally rich in the photographically active rays, it is more powerful than a simple candle-power measurement indicates. May I suggest to manufacturers that before it is fixed on the optical train they should discover in what direction it emits most light, and fix it accordingly? At present the direction used appears to depend on other considerations altogether.

(3) It should be possible to pass from transmitted to vertical illumination quickly and without having to make a number of delicate adjustments. Among the unsatisfactory methods at present put on the market I have come across the following:—(a) Change the microscope to a vertical position and use a vertical camera; (b) swing the optical train through a right angle round a vertical axis; (c) move the optical bench parallel to itself and insert a mirror inclined to the beam at 45°. The last is undoubtedly the method requiring the least complication of apparatus if properly designed;

but some of the applications of it are very crude. A fourth method appears to be possible, *viz.*, to keep the optical train fixed, but to deflect the light three times at right angles by total reflexion prisms, and so throw it into the vertical illuminator. As the last prism would be a small one, it could well be carried by the moving part of the microscope; it would not then require adjustment as the microscope is focussed.

(4) It would be a great advantage where the action of solutions is to be followed and recorded, if a horizontal camera could be used when the slide carrying the object is horizontal; this would combine the advantages of a horizontal camera and a vertical position for the microscope tube. I have not seen any attempt at this in an English apparatus.

In conclusion, may I say that the textile industries in the past have been among the least scientific of the large trades, but the need for research is now fully recognised. In such research the microscope and physical apparatus generally must play an important part. As one who is keenly interested in the technical applications of science, I hope instrument makers will make themselves acquainted with the requirements of the industry and will endeavour not only to meet them, but, if possible, to anticipate them. As a small step in this direction I suggest that *The Journal of the Textile Institute* should find a place on the shelves of their works library.

A series of papers dealt with the use of the microscope in metallurgy. The subject was introduced by **Dr. W. Rosenhain, F.R.S.**

In view of the lateness of the hour, there will not be time for me to read the paper which I have prepared; therefore I will only deal with one or two points which I think are more relevant to the aspects of the whole question which have already been discussed. I should like to say one or two words with regard to the question of increased magnification and increased resolving power for metallurgical work. There can be no question that we are dependent to a large extent for further progress in certain directions in metallography on obtaining higher resolution and higher magnification, but it has been clear to many of us for a long time, and to those to whom it has not been clear it will be so after having listened to these discussions, that magnification alone is quite useless, and that what we must look for is higher resolving power. Mr. Barnard has emphasised the theoretical possibilities of using a much shorter wave-length. No doubt in the future it may be possible to do that, and Mr. Barnard himself has been singularly successful in utilising the short wave-length of invisible light for photomicrographic work on transparent sections. About seven or eight years ago I was able to obtain at the National Physical Laboratory a complete outfit of Zeiss apparatus for this purpose, and I spent a large amount of time—over a year—in endeavouring to use it for metallographic purposes, but the result on the whole was extremely disappointing. I succeeded in getting a few photographs, but the time occupied and the labour involved were enormous, and when I did succeed it was only with moderate magnifications. The attempt to use high power monochromatic immersion lenses failed entirely, owing to the fact that I always got milky images. Fluorescence occurred whenever the ultra-violet light struck any object within the tube. When the beam of ultra-violet light has to be sent through a reflector and through the objective, fluorescence occurs on the objective itself, and as a result the light reflected from the back of the objective all over the tube—the actual visible light due to that fluorescence—became very serious in its actinic effect on the photographic plate, and I felt the only possibility of proceeding at all would be if a filter could be obtained which would exclude visible light and transmit the ultra-violet light almost undiminished. Prof. R. W. Wood, of Baltimore, suggested the silvering of one of the lenses, but that increased the exposure so enormously that it was hopeless. Other circumstances arose, and the matter had to be left aside. I hope someone may succeed in overcoming these difficulties, but I am not sanguine of the results which can be obtained with any kind of invisible radiation, and my reason is that such methods will only yield photographs. Photographs are extremely useful as a record of what you have seen, but as a means of actual microscopic examination they are not satisfactory. I always think it is necessary to examine successively large areas, and that you cannot, by using a few photographs of small areas, form a really good opinion.

There is one other direction in which I think that higher resolving power is at any rate conceivable. Resolving power is a function of the numerical aperture expressed in terms of u sin a. Sin a cannot be increased very much, but what about u? The immersion liquid is a difficulty, but I think that a higher refractive index for the front glass is at any rate a thing where there is hope of success as the result of research. I agree with Sir Herbert Jackson that research will make it possible to make glasses of almost any desired kind; there is, however, a good deal of emphasis to be placed on the "almost," because the range of possible glasses is strictly confined within certain limits of refractive index. I have on a previous occasion given the values of these limits, and the limitation is due apparently to quite definite physical and chemical causes. Glasses having very low refractive indices or high ones, and having abnormal optical properties, are virulent chemical agents in their action on everything they may come in contact with, including air. They are rapidly attacked by moist air, and they crystallise during manufacture. There, I think, lies the solution of the problem. When we look for substances which have high refractive indices, we find them in crystals, and I want to carry that suggestion one step further. I made it many years ago, but with the renewed stimulus to research in this direction, it is worth making it again. The time has surely come when we should meet this question of crystalline substances for optical purposes by attempting to grow crystals artificially. I am quite sure that it can be done, and it ought to be done. I have made a few preliminary experiments of that kind, and have succeeded in producing some small calcium carbonate crystals. They were small, but they were large enough for short-focus lenses, and I think the idea of growing crystals is not altogether out of the range of practical possibilities to-day.

THE METALLURGICAL MICROSCOPE.

By Walter Rosenhain, D.Sc., F.R.S.

(The National Physical Laboratory.)

In a paper* presented to the Royal Microscopical Society in 1906, the present author has described a Metallurgical Microscope in the design and construction of which an effort has been made to apply certain principles which he regards as fundamental for the construction of scientific instruments in general and of microscopes in particular. These principles have previously been discussed in a paper† presented to the Optical Convention, 1905. For the purposes of the present discussion, therefore, it will not be necessary to do more than to summarise briefly some of the principal points affecting the metallurgical microscope.

In regard to mechanical design, the primary consideration is that of providing adequate strength and stiffness not only in the base and limb, but also in the working joints, such as that upon which the limb turns. The design of such an instrument should, in fact, in the author's opinion, be based rather upon that of a machine tool than on the unduly delicate, sometimes flimsy, and often unmechanical devices which are to be found in some scientific instruments. One fruitful source of lack of rigidity may be found in the presence of unnecessary movements; for instance, it is now fairly generally accepted as an essential feature of metallurgical microscopes that the focussing movement, at all events so far as the coarse adjustment is concerned, should be applied to the stage. The provision of a coarse focussing movement for the body tube as well, therefore, constitutes an undesirable duplication. If the fine adjustment is also applied to the stage, as has been done in the author's design, then the body tube can be rigidly attached to the limb, with a corresponding gain in rigidity.

Another source of unsteadiness lies in the manner in which the so-called vertical illuminator is frequently attached. Where this fitting is screwed to the nose-end of the body tube and the objective is screwed into the illuminator, a certain amount of play is liable to occur. The author, therefore, very much prefers an arrangement by which the objective is screwed direct to the body tube, and the illuminator is inserted into the body tube, by means of a slide or otherwise, through a lateral aperture.

The application of the fine focussing adjustment to the stage offers a further advantage which is of some importance, as by this arrangement the fine focussing movement can be placed in an axial position. If this is done there is no overhang to magnify the slight play which is unavoidable on all smooth running slides. This

* "On an Improved Form of Metallurgical Microscope," Journal Royal Microscopical Society, 1906.

† "The Mechanical Design of Instruments," Proc. Optical Convention, Vol. 1, 1905.

difficulty might perhaps be overcome in another way by adopting geometrical contacts instead of plain sliding contacts. The advantage of this system has long been recognised in theory, but instrument makers do not appear to have seen their way to its adoption on any large scale.

The illuminator and its adjustments deserve a little further consideration. Both for visual and photographic purposes the author has found it a very great advantage to have an illuminator whose position is capable of a very considerable range of adjustment. Whatever form of reflector be employed, it is always an advantage to be able to adjust its position not merely by rotation but by lateral and longitudinal movement in the tube. This is important, not only for the purpose of securing illumination at the precise incidence best suited for showing any particular feature, but also for the purpose of eliminating that most fruitful source of difficulties—internal reflections from the lenses of the objective.

Two further features of the mechanical design are of some importance. The first of these is the provision for a large working distance between stage and objectives. This is necessary not only to provide for the examination of thick specimens, but also because for many purposes the use of long focus objectives is necessary. This latter aspect of metallurgical work is assuming increasing importance at the present time owing to the fact that the study of macro-structures is now demanding much greater attention. In many cases these macro-structures are large enough to be photographed with an ordinary camera or even to be reproduced by means of direct contact printing. There are, however, many conditions in which the macro-structure is still sufficiently small to require magnifications of from 2 to 10 diameters, and it is very convenient for those who are not in a position to set up a separate apparatus for this purpose if their metallurgical microscope is capable of being used with long focus objectives working either with or without an eye-piece.

Another matter of some convenience in the metallurgical microscope is the provision of a complete rotation of the stage together with a simple centering device attached either to the stage or to the nose-end of the body tube. Rotation of the specimen is important for two reasons:—In the first place under oblique illumination the aspect of an etched surface varies in a most instructive manner with varying incidence of the light, and it is sometimes convenient to apply coloured illumination from two or more directions, and to be able to rotate the specimens under such illumination. In the second place, when a vertical illuminator is used which covers one-half of the aperture of the objectives, the resolving power is much greater in the direction parallel to the edge of the illuminator than in the direction at right angles to it.

Consequently in examining such a structure as finely laminated pearlite, this may appear uniform or " sorbitic " when viewed in the one position, while it becomes clearly resolved into laminae when turned through a right angle. This, of course, applies mainly to work at high magnifications under lenses of large resolving power.

Turning to the optical equipment of the metallurgical microscope, there can be no question that the requirements of metallurgy demand the best and even more than the best that optical achievements can

provide. The requirements themselves are mainly those common to all microscopic work of the most exacting kind. In regard to the provision of the most critical definition, the highest possible resolving power and the largest and flattest field, together with the greatest possible approach to freedom from colour and the elimination of differences of actinic and visual focus, hitherto the best appo-chromatic lenses have provided the nearest approach to a fulfilment of these requirements. Metallurgical progress, however, undoubtedly tends increasingly to the production of materials having an extremely minute micro-structure, and the differentiation of these and the reading of their life history from their structure, makes increasing demands upon the resolving power of our lenses. The provision of a resolving power which should allow the employment of a much higher useful magnification becomes, therefore, of very considerable practical importance. Whether or not such an achievement is within the range of possibility is a matter for the optician rather than the metallurgist. The difficulties of the problem must, however, be very fully recognised; one of the most important, no doubt, resides in the difficulty of finding an immersion liquid, of very much higher refractive index than the cedar-wood oil commonly employed. The use of monobromonaphthalene immersion objectives has been tried, but they do not appear to have achieved any wide-spread use. An effort has also been made to meet this requirement by the use of light of much shorter wave-length. The author has spent a considerable amount of time in endeavouring to use the Zeiss ultra-violet microscope for metallurgical purposes, and has succeeded in obtaining a few micrographs by this means. He has, however, abandoned his efforts, because the expenditure of time required was much too great, while the results themselves were not particularly satisfactory. One of the main difficulties in his experience arose from the internal scattering of the ultra-violet light and the occurrence of fluorescence within the microscope tube. Even should it be possible to overcome these difficulties, a process which is entirely photographic, and in which the systematic visual examination of relatively large area of specimens is impossible, does not promise a very large range of utility.

Reverting to the requirements for objectives of the ordinary type intended for metallurgical use, there is one point which requires special emphasis and attention. Clear images, whether visual or photographic, can only be obtained if serious reflections of light from the back surface of the objectives can be avoided. As has been indicated above, this is partly a question of careful adjustment of the light and of the illuminator. With the best of facilities in that direction, however, the author's experience has shown very clearly that different lenses of the same focal length differ very widely in respect of this matter of internal reflections. This appears to be a question of the shape of the back lens of the objective, and especially of the outer surface. Where this is plane it appears to be possible to catch the whole of the reflected light on the mirror or prism of the illuminator, but where the back surface is convex this becomes impossible, and a milky image is very apt to result.

In regard to eye-piece requirements for metallurgical work, these do not appear to differ from those of other microscopical purposes; there is, however, from the user's point of view, a distinct objection

to the use of eye-pieces such as the compensating eye-piece of Zeiss, which can only be used with a particular series of objectives. Unless, therefore, such an arrangement is really essential to allow the best results to be obtained, it will be very much preferable to have eye-pieces and objectives self-contained and interchangeable, not only with other lenses of the same series, but as nearly as may be universally. It may be desirable to state from the author's practice and experience the most useful focal lengths for objectives and magnifications for eye-pieces. It should perhaps be said that it is not suggested that any rigid standardisation of magnifications should be adopted by metallurgists. While a certain degree of uniformity of practice and especially the avoidance of odd magnifications are no doubt desirable, any attempt to tie down microscopists to a few specified magnifications is eminently undesirable, since the magnification for each subject should be chosen specifically to suit that subject. A range of objectives and eye-pieces is, therefore, in the author's opinion, desirable, which will allow of almost any desired magnifications being obtained in a satisfactory manner, that is, by use of an objective of adequately resolving power and without employing a high eye-piece or an unduly extended camera, where photographs are concerned.

The lenses ordinarily used by the author have focal lengths of:—

$$\left.\begin{array}{r}16\text{ mm.}\\ 8\text{ mm.}\\ 4\text{ mm.}\end{array}\right\}\text{ dry series.}$$

$$\left.\begin{array}{r}2\text{ mm.}\\ 3\text{ mm.}\end{array}\right\}\text{ oil immersion.}$$

Eye-pieces—$\times 8$, $\times 12$, $\times 18$.

These lenses have been used because they have been commercially available in those makes which have in the past produced the finest results. So far as the objectives of the dry series are concerned, the focal lengths stated fulfil all ordinary requirements, although a 4 mm. dry objective is not easy to use and requires a great deal of stopping down of the beam of incident light. For this reason, the author, some time ago, suggested the desirability of an immersion lens of from 5 to 7 mm. focus. This would have the great advantage of affording a greater depth of focus than the 4 mm. dry objective, but it might prove difficult to use in a horizontal position unless a special device were provided for holding the oil in place.

With regard to the immersion objectives, that which has given the finest results for the highest magnifications in the author's practice, has been a lens of 3 mm. focus with N.A. 1.40. Unfortunately, these lenses are very delicate in use, and require not only protection from mechanical injury, but also from any agency which affects the cement with which the front lens is attached to the mount and from prolonged exposure to contact with immersion oil. If the latter is not of precisely the right quality, this is alone sufficient to do damage. If this oil is wiped away very gently with a soft cloth and the surface of the lens is then wiped lightly with an old handkerchief slightly moistened with benzol, damage to the cement may be avoided for a long time.

Beyond the objectives named above, a demand exists, and is becoming increasingly important, as indicated above, for first-class objectives of long focus. The author would welcome such objectives having focal lengths of 30 mm., 50 mm. and 75 mm., suitable mainly for photographic purposes. It would, however, be an advantage if they could be designed to work with a low power eye-piece so that they could also be used for visual work.

The accessories required in metallurgical microscopy are of some importance. A satisfactory illuminant is essential to all good work of this kind. For visual purposes, the requirements are easily met,

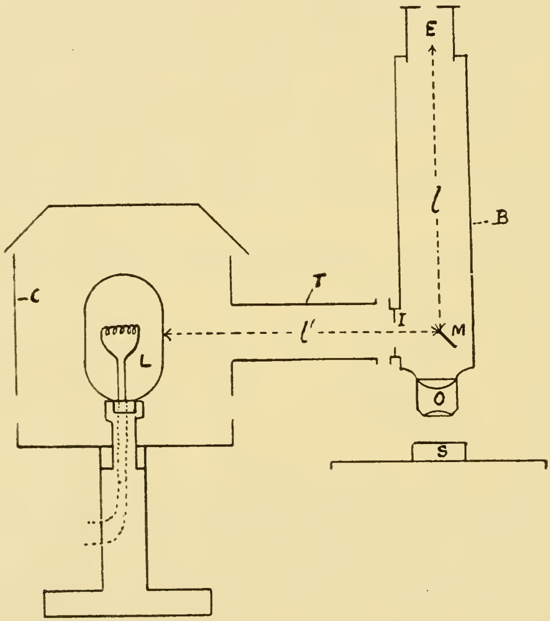

FIG. 1.

since it is only necessary to place opposite to the lateral aperture of the illuminator an uniform source of light having a reasonable area (about 2 centimetres in diameter). Such a source of light may be obtained by placing a suitable burner or electric lamp behind either very finely ground glass or a thin piece of opal shade. If the luminous surface thus produced is placed to one side of the microscope in such a position that its distance from the illuminator mirror is equal to the distance from that mirror to the back focus of the objective, the result is an approach to the conditions of "critical illumination," and for visual purposes these are certainly the best conditions obtainable. This arrangement has the further advantage that no lenses, condensers, etc., are required, and that an iris diaphragm placed just outside the illuminator aperture is all that is needed to regulate the illumination. The whole arrangement can be very simply made by mounting the lamp with a short external tube through which the light passes to the illuminator, the rest of

the lamp being enclosed in a light, tight, but suitably ventilated, case. If the lateral tube through which the light passes is made of the right length, all that is necessary for setting up the illuminating arrangement is to switch on the lamp and to place the small tube almost but not quite in contact with the rim of the iris diaphragm outside the illuminator. A diagrammatic section of this whole arrangement is given in Fig. 1, and a photograph is shown in Fig. 2.

For photographic purposes, the intensity of the illumination obtainable in this way is not large enough to be convenient. The author has endeavoured to use one of the small tungsten arc-lamps known as "Pointolite," as the source for critical illumination in photography, by placing the lamp itself in the conjugate focus position. But with the largest size of this type of lamp at present available, the illuminated area is not large enough. It is to be hoped, however, that a larger form of this lamp may become available, and in that case it will be possible to carry out the best kind of micrographic work without the use of a system of condensers, such as are employed at present.

The arrangements for fine focussing of the microscope when used for photographic purposes frequently present imperfections which are annoying in use, and are liable to lead to the loss of photographic material. Whether gearing or a cord serving as a belt are employed, there is always apt to be some degree of lateral pull applied to the microscope when the fine adjustment head is turned by the operator working from the screen end of the camera. The author has devised a very simple means of avoiding this difficulty and of leaving the microscope free as soon as the operator's touch is removed from the focussing rod. For this purpose, the focussing rod, extending along the length of the camera, operates by means of a small belt, a rotating spindle attached to an independent bearing carries on a separate stand. This rotating spindle is so placed as to be axial with the fine adjustment of the microscope, in whatever position this may be situated. The end of the spindle nearest the microscope merely carries a cross-piece consisting of a thin rod. Fixed to the fine adjustment head of the microscope itself is a light tube of brass or aluminium. In this tube are two longitudinal slots diametrically opposite one another. The independent spindle above mentioned runs down the axis of this tube, but the transverse rod has its ends projecting through the slots of the tube, the slots being made a little wider than the diameter of the rod. If now the spindle is rotated by the operator turning the focussing handle, no pull whatever is placed upon the fine adjustment of the microscope—the motion of the spindle being transmitted to the fine adjustment through the slots in the tube. In these circumstances, a pure turning moment or torque is applied to the fine adjustment, so that there is no tendency to displace the microscope. Further, if the belt connecting the focussing handle to the moving spindle is slightly elastic, the moment the pressure of the operator's hand is removed from the focussing handle, the spindle and the transverse rod which it carries will spring back by a very small amount. In this way, the rod is brought out of contact with the tube, and the microscope is left entirely free from contact with the focussing gear.

If the fine adjustment of the microscope is of the ordinary type in which the head has only a very small longitudinal motion, the tube, slots, and spindle mentioned above also need only be very short. On the other hand, in the type of microscope designed by the author, in which the fine adjustment may be moved through considerable distance by the coarse focussing of the stage, the tube, slots, and spindle must have a length of several inches. This focussing device, which is somewhat difficult to describe in words, is very simple and efficient in action. It is illustrated in the photograph, Fig. 3.

Finally, reference may be made to another matter which sometimes gives difficulty in metallurgical microscopy. This is the mounting of specimens with their surfaces accurately at right angles to the optic axis of the microscope. Mechanical levelling devices of various kinds have proved more or less successful, but they all have the serious disadvantage that the carefully prepared surface of the specimen must be placed in contact with some part of the apparatus, and when this is done there is considerable risk of damaging the surface. The author, therefore, has devised an optical levelling appliance in which the surface of the specimen is utilised as a reflector. The specimen is approximately mounted on a glass slip by means of plasticine, wax or other soft substance. It is then placed under the instrument, and its position is adjusted with the fingers until the reflection is seen opposite a cross-wire. When this position has been obtained, the specimen is accurately level, and the manipulation is so easy that it rarely occupies more than five seconds. A more detailed description of this device has been given in the author's paper on "Some Appliances for Metallographic Research."*

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* Journn. Institute of Metals, 1915, I.

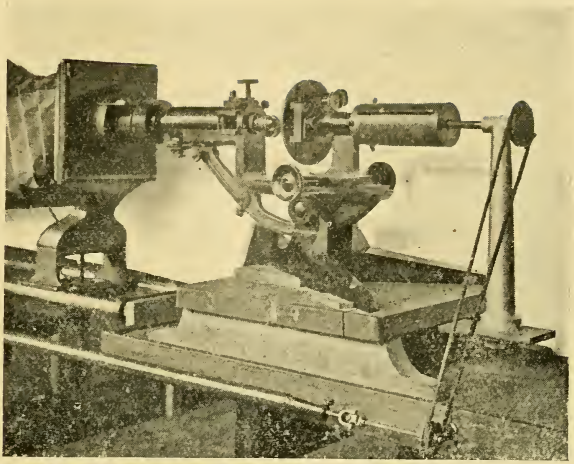


Fig. 2.
Independent Focussing Device applied to Metallurgical Microscope as used for Photography.

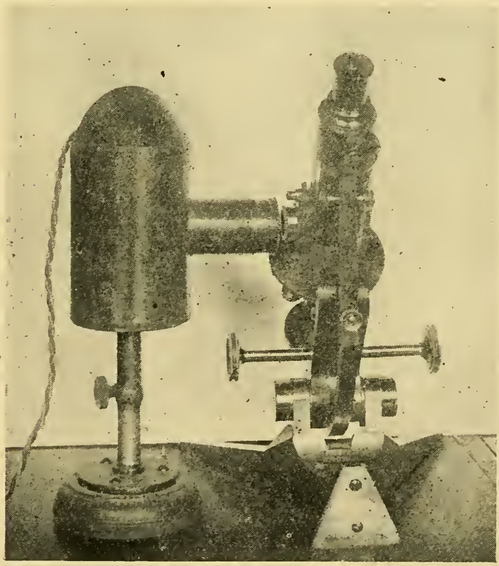


Fig. 3.

NOTES ON THE CONSTRUCTION AND DESIGN OF METALLURGICAL MICROSCOPES.

By Prof. Cecil H. Desch, Glasgow.

The use of the microscope in the examination of metals, first introduced by Sorby more than 50 years ago, has become so widespread that a microscope is now an indispensable item in the equipment of a metallurgical works, whilst the recognition of its importance to engineering works and other places in which metals are employed for constructional purposes is rapidly extending. It is therefore essential to the conduct of these industries that instruments should be available which will allow of the rapid and convenient examination of such metals as present themselves in the course of routine testing, whilst it is obviously desirable that elaborate and detailed investigation of specimens of special interest should be possible. It is quite true that any ordinary microscope of good construction may be used for metallographic work, provided that the higher power objectives are duly corrected for uncovered objects, but the increased convenience of a properly designed instrument is so great as to justify its use, even for routine work. There are now many patterns of metallurgical microscopes on the market, and the following remarks are based on an experience of some 12 or 13 types of instrument, and the examination of the details of many others. The writer has been reluctantly forced to the conclusion that, in spite of many excellent features in some of the British microscopes, the German instruments have proved better in use, and that their superiority is more marked, the longer the microscopes are used. The British designs are often good, and the workmanship, so far as the cutting of racks and screw-threads, etc., is concerned, is often quite satisfactory, but in the course of prolonged use the mechanical arrangements show defects, racks and screws becoming loose, and the accurate focussing of high power objectives becoming troublesome, to an extent which is not met with in the German microscopes. The cause of this looseness after use appears to be insufficient attention to the quality of the metal employed in construction. A rack cut in soft brass, however accurate at first, becomes loose through wear, and no compensation by means of adjusting screws can be quite satisfactory. The fact that such screws are provided seems to be a confession of weakness, since the writer has used a Zeiss microscope, without such screws, for years continuously without any sign of play in the mechanical movements. Racks should be cut in hard, incorrodible metals or alloys instead of in soft brass, whilst the pinions might also be of much harder metal than is usually the case. It is probable that manufacturers have been too much guided by tradition in the choice of the metals to be used in the construction of scientific instruments, witness the tendency, only now disappearing, to use highly polished brass for heavy portions where cast iron would serve the purpose equally well.

The principal parts of the metallurgical microscope may now be considered in succession.

(a) *The Stand.*—There is no reason why the shape of the medical or biological microscope should be slavishly copied in the construction of metallurgical instruments, whilst there are many reasons for choosing a different form, especially when there is a possibility of large specimens being examined. The tripod form of foot, so convenient in work by transmitted light, is awkwardly in the way when examining metals and having occasion to use the rackwork movement for raising and lowering the stage. The Jackson foot is better, and a heavy horseshoe foot still better, as heavy specimens, such as rail sections, may be laid on it for examination under low powers. This is further facilitated by making the bracket which holds the stage capable of swinging to one side, and leaving a clear space between the objective and the heavy horseshoe foot, as in the old vertical Reichert microscope. Special forms of foot, as in the Beck-Rosenhain microscope, have the advantage of great rigidity in both the vertical and horizontal positions. This stand is the most rigid of those examined. The design of Sauveur's universal Metalloscope is also unconventional, and appears to be good, but the writer has no actual experience of it. For photographic work the form adopted in the Zeiss-Martens instrument and in Watson's horizontal microscope is both convenient and steady.

The inverted stand, due to Le Chatelier, has been copied by several makers, but the construction is apt to be flimsy, and the writer has found great difficulty in moving even small specimens on the stage without altering the focus, the light arms which support the optical parts being liable to whip. This could perhaps be overcome by better engineering design, and the type is certainly preferred in some works on account of the rapidity with which specimens can be inserted and examined. The optical conditions of this form are discussed below. It is probable that for the larger instruments to be used for photography the ordinary type of stand might be departed from entirely, and an arrangement modelled on the optical bench adopted, the various optical parts and specimen carriers being supported in such a way as to move freely along a heavy bar of geometrical form to preserve alignment.

(b) *Coarse Adjustment.*—The rack and pinion should be geometrically cut in metal of sufficient hardness to withstand prolonged usage without working loose. The improvement in the methods of gear cutting in engineering practice has been so great in recent years that much would be gained by adopting the methods of marine engineering shops in the instrument maker's workshop. In large instruments, the length of travel might well be greater than at present, so as to allow of a wide range of objectives, and stops should be provided at the ends of the rack to prevent over-

racking. This is particularly desirable in students' microscopes, as it would prevent a common accident in laboratories where inexperienced students use the instruments.

(c) *Fine Adjustment*.—This does not call for much remark, as there are several good forms in use. The speed is sometimes made too great for comfortable focussing of high powers. The side arrangement of small milled heads is perhaps the most convenient.

(d) *Body Tube*.—This should be of the short Continental form, and preferably of wide diameter. The latter condition is essential in instruments to be used for photographic work, and should always be adopted, but it has also great advantages for visual observation, and can be introduced without interfering with the general design.

(e) *The Stage*.—A plain stage of fairly large size is suitable for most ordinary work. It should be provided with a rack-work focussing movement, but a fine adjustment is unnecessary. A central hole, sufficiently large to allow an objective to pass through it, allows of the examination of heavy specimens resting on the foot, unless the support of the stage be arranged to swing aside entirely, as mentioned above. Levelling stages are a nuisance, and should never be used. The specimen should always be levelled before placing on the stage, either by means of plasticine and one of the usual mounting devices, or by means of Dr. Rosenhain's auto-collimating instrument. Mechanical movements to the stage are essential for high power work, and rotation is also a very great convenience, but when both are provided the rotation should be concentric. A rotating plate which is carried by the traversing movements is useless. When a microscope is intended to be used in the horizontal position, it is desirable to provide the mechanical movements with clamping screws, as otherwise a heavy specimen may cause a gradual downward slip during the exposure of a photograph, pulling down the rackwork by its own weight. This has often been noticed when photographing at high magnifications. The rotating circle should have a clamping screw. The Zeiss-Martens stand has a very convenient rotating and traversing stage, but the range of movement is too limited.

The examination of fractures, large crystals in ingot sections, and other things requiring very low powers and great distances, is troublesome when an ordinary microscope is used, and it is often preferable to employ a camera with a landscape or copying lens instead of a microscope. The telephoto attachment of the Davidson microscope gives good results in this kind of work, and the arrangement in the recent pattern, by which the object is carried on a separate stand, movable along a base board, is convenient. On the other hand, the writer does not approve

of the "super-microscope" arrangement, by which the image formed by one objective is magnified by a second objective.

(f) *The Vertical Illuminator.*—Whilst the prism form has the advantage for visual work of causing much less loss of light than the transparent plate, it is unsuitable for high powers, on account of the fact that it only uses one-half of the aperture of the objective, and is consequently liable to produce false images of fine structures. The same objection applies to silvered half-discs or other similar devices. The Beck or transparent illuminator is the only suitable form for photographic work at any but low magnifications. The mistake is very commonly made of fitting a small cover glass, which only imperfectly covers the back lens of the objective, into such illuminators. A plate of larger size should be used. Moreover, cover glasses are not accurately flat, and have no advantage except cheapness and thinness. A large, optically worked plate is used in the Conrady-Watson illuminator and in the Jackson and Blount microscope. The writer has found the thin, square plates used for counting blood corpuscles very suitable, being sufficiently flat and so thin as not to produce doubling of the image. The plate should be capable of at least partial rotation, and should have a sufficiently large milled head to allow of delicate adjustment. Vertical illuminators often leave much to be desired in regard to mechanical construction.

The inverted or Le Chatelier type of microscope calls for a different form of illuminator. As usually constructed, the numerous reflections required tend to injure the definition of the image and to cause loss of light. To a great extent this might be obviated by better optical workmanship, the prism being made in one piece with accurately ground faces, as in the modern range finder. The possibilities of new optical arrangements for illumination are not exhausted.

(g) *The Objectives.*—It is now generally agreed that short mounts are to be preferred for metallographic objectives. A high numerical aperture is necessary for the highest powers. Apochromats are usually recommended for the medium and high powers, but such objectives are commonly deficient in flatness of field, a very desirable quality in metallographic work, and it may be questioned whether good achromats, giving flat fields, are not to be preferred for photographic purposes. It is usual to insert a colour screen when making such photographs, and now that screens which transmit so narrow a band of the spectrum that they may be regarded as practically monochromatic are obtainable, it seems of less importance that the colour correction of the objectives should be perfect. Oil immersion objectives are, of course, necessary for the highest magnifications.

(h) *Eye-pieces.*—These give the least trouble of all the parts of the microscope, the quality being usually satisfactory. Projection eye-pieces are to be preferred for photographic work.

These few notes are presented by way of suggestions for discussion. Each worker will have formed some opinion on the points mentioned, and a comparison of such opinions may be of assistance to manufacturers in determining the design of their future instruments. There is a large demand for metallographic microscopes at present, whilst the supply is very limited, and the time seems appropriate for a consideration of the question whether improvements might not be made in the light of experience.

SOME NOTES ON THE METALLURGICAL PHOTOMICROSCOPE.

By J. H. G. Monypenny.

(Chief of the Research Laboratory, Brown Bayley's Steel Works, Ltd.)

The technique of the photomicrography of metals has advanced very much during the last ten or twenty years, but there are still very marked evidences that many who take up microscopic work in connection with metallurgy appear to study the microscope itself either not at all or only to a very small extent. The consequence is that statements are made about the structures of various metals which are not correct; the presence in sections of minute particles or membranes of constituents other than those stated to be there has been missed simply because the operator did not know how to use his microscope properly. Again, photographs are published which have only a slight resemblance to the structures photographed, in some cases the definition is so bad that the reproductions are not worth the paper they are printed upon. One has only to look through the Journals of, for example, the Iron and Steel Institute to see how true this is.

Even when a metallurgist has devoted a considerable time to the study of the microscope, mistakes may arise in the interpretation of structures. For example, it has been stated that iron carbide (cementite) is not attacked by sodium picrate when its thickness is less than 0.001 mm. (this statement is repeated in one of the most recently published treatises on metallography). This is quite incorrect. Not only are the carbide laminae of pearlite attacked when considerably thinner than this (certainly not more than one-tenth of the thickness mentioned), but also the minute granules in sorbite, produced on tempering hardened steel at about 600° C. Possibly the reason the above misstatement was originally made was either that the aperture of the objective used was not sufficiently high or that the resolving power was much reduced by the use of a prism illuminator or both.

In the following pages the author has attempted to set out some of the conditions which appear to him to be necessary to secure good photomicrographs of metals and the means he has devised from time to time to fulfil these conditions.

(a) *The Illuminant and Condensing System.*—Few who have had any experience in photomicrography will disagree with the statement that the illumination of the specimen is of fundamental importance in the production of a good photomicrograph. Good illumination should comply with the four following conditions:—

(1) The whole surface which is required to be reproduced should be evenly illuminated.

(2) The lighting should be such that the whole aperture of the objective may be utilised.

(3) The wave-length of the light used should be that for which the objective is corrected.

(4) The wave-length of the light used should be suitable to the colour of the specimen.

Fortunately, in most metallurgical work the specimens rarely call for the use of any definite colour of light, and hence the necessity for complying with condition No. 4 does not, in general, arise. This is a great advantage, as it enables one to adjust the colour of the light to fulfil condition (3). In other branches of microscopic work (*e.g.*, in connection with Biology), it may easily occur that the requirements under conditions (3) and (4) are opposite, and then the photomicrographer has either to use a colour for which the objective is not adequately corrected or which is not best suited to the specimen.

In metallurgical work the objective acts as condenser, and it is well known that to produce "critical illumination" the illuminant should be focussed on the section, and should therefore occupy the

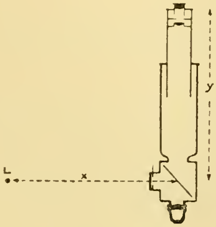


FIG. 1.

Diagram showing conditions for critical illumination.

position L shown in Fig. 1, so that the distances x and y are equal. Practically it is found that the illuminant may be to some extent out of focus without producing any bad effect, providing the objective transmits a full solid cone of light. This may be judged by looking at the back lens of the objective after removing the eye-piece, when (the iris on the vertical illuminator being open) the back lens will be full of light and evenly bright if critical illumination has been obtained. The fact that the illuminant may be to some extent out of focus is of great value in allowing one to get rid of the effect of small surface markings on the illuminant itself.

Placing the illuminant in such a position has obvious disadvantages, *e.g.*, it would be inconveniently close to the microscope and the heating effect produced on the latter would be considerable. Again, to illuminate the whole visible field in the microscope, the illuminant would have to have an evenly bright area at least as large as the diaphragm of the ocular in use (say 7 to 8 mm.), obviously, therefore, illuminants of small area (*e.g.*, Nernst or Arc lamps) could not be used in this way.

As regards the illuminant, the author prefers the 500 C.P. Pointolite Lamp (a tungsten arc lamp made by the Ediswan Co.) to any other type of lamp made; the intensity of the light is very great, and it is absolutely steady. It requires direct current, and where this is available the author has no hesitation whatever in recommending it in preference to any other form of illuminant. Previous to this lamp being on the market (about 1917), the author had tried a Nernst lamp, an arc lamp, and lime-light, and had for some years used the last in preference to the first two. The intensity of the light given by the lime is not nearly so great as with the arc lamp, but on the other hand it is perfectly steady, and this cannot be said of the arc lamp.

Coming to the condensing system, probably one of the simplest arrangements is that shown in Fig. 2. In this case the condenser C forms an enlarged image of the illuminant L at L_1, the correct distance from the illuminator to give critical illumination as described earlier. By this means the area of the illuminant is spread out, and with, for example, lime-light, one may obtain perfectly even illumination even when photographing at, say, 5 or 6 times the initial power of the objective. The effect of any slight irregularities

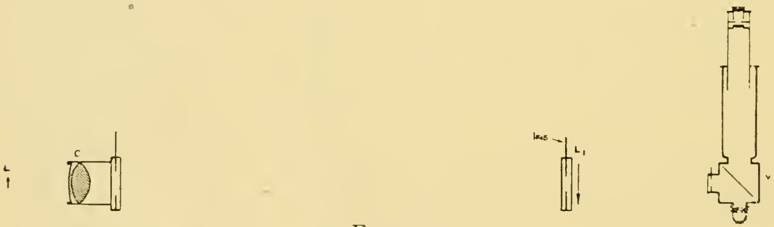


FIG. 2.
Condenser System No. 1.

on the surface of the illuminant may be avoided by forming the image L_1 about 1 in. nearer the microscope than its correct position, as mentioned earlier. It is advisable to have an iris diaphragm at L_1 and to close it until only slightly more than the area to be photographed is illuminated. This cuts off a lot of stray light which would otherwise reduce the contrast by giving a general fog over the whole section. This iris should be focussed fairly accurately on the section, otherwise there is a gradual falling off of the illumination on the edge of the field instead of a sharply defined edge to the illuminated area.

While this method is perfectly satisfactory for use with lime-light —the author has taken several hundred photographs at magnifications ranging from 30 to 2,000, using an arrangement of this description—it has certain drawbacks; for example, a great deal of light is wasted, and with an illuminant of small area it is difficult to fill the field evenly unless a very long optical bench is used.

These defects are obviated in the following arrangement. In this, advantage is taken of the fact that if a biconvex lens is held between the eye and a light (*e.g.*, a candle flame) in such a manner that the eye and flame occupy the position of conjugate foci then the lens itself will appear to the eye as an evenly illuminated disc, and

for the purposes of microscopic work may be looked upon as an illuminant. There is one essential point, however, the beam of light thrown by the lens must cover the whole surface of the back lens of the objective, otherwise some of the aperture of the latter is lost.

In Fig. 3, A represents a lens of about 6 in. focus, placed at the requisite distance from the microscope to give critical illumination, as described earlier; the objective therefore uses this lens as the illuminant, and forms an image of it in the field (if any slight scratches are present on the surface of the lens, it should be moved very slightly out of focus). Condenser B (about $2\frac{5}{8}$ in. focus and $2\frac{1}{8}$ in. diameter) is placed at such a distance from A that the

FIG. 3.
Condenser System No. 2.

latter focusses B approximately on the objective. Finally B forms an enlarged image of the illuminant on A. This sounds rather complex, but the result is that if the eye be placed at A, B appears as an even disc of light, and similarly to an eye placed against the objective A appears as an even disc. As mentioned above, the only point that must be carefully watched is that the image of B formed by A on the objective must at least cover the back lens of the latter. The figures given above refer to the author's arrangement, and in this case the image is rather more than two-thirds of an inch diameter, and therefore amply large enough for any objective in use. Condenser A need not be more than 1 in. diameter, but the image of the light formed on this lens by B should completely fill it. This condenser (A) should have an iris diaphragm for limiting the area of the field illuminated as described earlier. An iris is not required on condenser B, except for centering and focussing purposes.

Using this arrangement, one is able to illuminate evenly the section, and also provide critical illumination. It will be found that if condenser A is used without B, unless the illuminant has a large area or is placed very near to A, the conditions of critical illumination are not obtained, the beam of light not being sufficient to fill the back lens of the objective. The effect is equivalent to cutting down the aperture of the objective, with all the bad effects produced thereby. The author has seen more than one metallurgical photomicroscope in use in which this condition of things has obtained.

It is obvious from Fig. 3 that, using an illuminant of small area, such as the Pointolite, condenser B should have a short focus, and also the better corrected it is the more light will be available—the author uses the Watson-Conrady condenser, and finds it excellent

for the purpose. Doubtless other opticians could supply similarly corrected condensers. Condenser A has a longer focus (the actual focal length will depend on the tube length employed and the distance between the condensers), and as it need only be of small diameter, such a high degree of correction as in B does not seem necessary.

(b) *The Vertical Illuminator.*—The author does not propose to enter into the question of prism *versus* disc illuminator to any great extent. The fact that with high powers a disc illuminator must of necessity give and does give far better definition and much more detail, is evident to anyone who has studied the subject or who has critically compared the two illuminators with the same lens on the same field. Examples of this have been published independently by Rosenhain and by Benedicks; the author (who was unaware of Rosenhain's work) investigated the matter before Benedicks' paper was published, and his results, though not published, were communicated to some of his friends. It is probably not so well known, however, that the results with low power lenses show the same differences, though not in so marked a manner. The differences produced for any given objective depend on the fineness of detail in the section. Other things being equal, the superiority of the disc becomes more marked as the detail to be reproduced becomes finer. The author always uses a disc illuminator even with the lowest powers, except under exceptional circumstances. (Such may arise in a low power photograph of an object showing no fine detail and possessing very little contrast.)

While, however, the author is convinced of the superiority of the disc illuminator, he has found that many individual discs are very poor specimens, and in this respect he would urge on instrument makers the necessity for more care in choosing material for the "disc." In many cases the glass is so thick and so uneven that the definition of even a low power lens in absolutely ruined. The author a few years ago received an illuminator from one of the largest microscope makers in England—he returned it at once with a note that it was useless owing to the bad glass (giving them details of the behaviour of the disc). The illuminator was returned to him with a fresh glass fitted, which was every bit as bad as the first one. The effect of this bad disc is shown in Figs. 4 and 5. These represent the same field taken with the same objective, ocular, plate, and screen, in fact every condition the same, except that in Fig. 4 the disc was a good one, while in Fig. 5 the disc was the bad one mentioned above. It was absolutely impossible to get any sharper definition than that shown in Fig. 5. The author suggests that this is a point to which instrument makers should give far more attention than they do—there is no doubt at all that many of the glasses supplied with disc illuminators are far too thick, and they are often uneven. It is evident also that the discs cannot be very carefully examined by the makers before being put into stock, otherwise such defects would be quickly discovered.

It may be of interest to mention that the bad disc mentioned above had far more effect on the performance of the 1 in. and $\frac{1}{2}$ in. objectives than on the 1-6th, probably owing to the larger area of the glass used by the former lenses. Probably this fact and the

prevalence of unsuitable material for the disc may account for the opinion frequently held that for such low powers the prism illuminator gives the better effect. A prism would give a much better result than Fig. 5.

There are three other points in connection with the vertical illuminator that the author would like to mention.

(1) The illuminator is rarely made large enough to fill the back lenses of the lower power objectives—for example, the 24 mm. N.A. .30 or the 12 mm. N.A. .65. The only disc illuminator known to the author which is large enough for these lenses is the large pattern made by Watsons, London.

(2) The illuminator should be fitted with an iris diaphragm, which should have some type of centering adjustment. This iris is used in the same manner as the iris on a substage condenser, and should therefore close absolutely central with the objective. Such adjusting movements as are found on the Watson pattern mentioned above are suitable.

In connection with the prism illuminator it is curious that in the pattern as ordinarily sold, the iris diaphragm closes concentrically with the middle of the front face of the prism, and therefore with a line about one-eighth of an inch from the centre line of the objective. The iris should, of course, close concentrically with the middle of the bottom edge of the prism, as shown in Fig. 6, where A indicates the centre line of the iris as ordinarily fitted, and B the line on which it should close. The effect, on the performance of an objective of short focal length, of closing the iris about line A can be imagined.

(3) One of the great defects of the disc illuminator, especially with the lower power objectives, is the presence of flare due to the reflection of the incident light by the outer surface of the back combination. This is a matter, however, which could probably be remedied to a great extent by the objective designer. It will be obvious that (other things being equal), the more convex this back surface is, the less the amount of flare, since more of the reflected light will be reflected on to the inner surface of the draw tube (and be absorbed by the blackened surface), and less will reach the eye-piece. The author has one lens in his possession in which the back surface is apparently slightly concave, and, owing to the amount of flare caused thereby, the lens, though a magnificent one from every other point of view (it is the Zeiss 12 mm. Apochromat N.A. .65) is not so valuable metallographically. The author would suggest that this is a point to which opticians could usefully give their attention in computing objectives for metallurgical work.

It is, of course, obvious that with the present method of construction of objectives there is much more likelihood of flare being obtained with apochromatic objectives than with achromatic—especially with the lower powers. In the former the back combination has very little magnifying power, its function being chiefly that of correcting the aberrations and other faults of the front combinations. In the simpler achromatic the back combination frequently has a considerable magnifying power. The more convex back surface of the latter type of lens will therefore cause less flare than the less convex surface of the more highly corrected combination. The author has frequently noticed this difference in

comparing the different types of lenses. Very often the effect of the flare can be overcome by using a combination of plate and developer which gives contrast easily; for example, such methods succeed perfectly with the 24 mm. Zeiss apochromat; with the 12 mm., however, as stated above, the flare is so great that the author uses for preference a very good achromatic lens of the same aperture.

(c) *Colour Screens.*—As mentioned earlier in the paper, the use of colour screens in metallurgical work is simplified very much, as it is only on very rare occasions that a section is obtained which requires light of some definite wave-length in order to get the best results, consequently the whole attention can be given to using the light most suited to the lens.

If the objective is apochromatic, light of any colour may be used, but it is generally advisable to use blue light in preference to green or red (especially with the higher powers), as the resolving power is thereby increased. It is *always* advisable, however, even with the best apochromats, to focus with the same colour light as is used for photographing. The author's general practice in this case is to focus with a blue screen in position (generally the Wratten tricolour blue), and then remove the screen and expose on a non-colour sensitive plate (all blue screens increase the exposure rather considerably). This method is perfectly satisfactory for the Zeiss apochromats, even at the highest magnifications.

With achromatic, or semi-apochromatic lenses, one has not the same freedom. Owing to the simpler construction of these lenses the correction for spherical aberration is taken to a high degree of perfection for light of one colour only (generally yellow green), and the best results are only obtainable by using this colour. The author has examined such objectives made by most of the leading makers in England, and has never met one in which the correction for spherical aberration for blue violet light was sufficiently good (compared with that for green light) to make it worth while taking photographs with such light. Some lenses were certainly better than others, and, curiously enough, some of the lenses which were very poor with blue light worked quite well with red light. The author is of opinion that it would be far better if this fact were more widely acknowledged by the makers. To read the catalogue descriptions of some of the lenses one would imagine that they would perform perfectly without any screen at all. The author has known of cases where objectives by well-known English makers have been purchased and used in the belief that they would perform well under these conditions. After seeing the results the purchaser came to the conclusion that the lenses were very poor specimens. In one case which occurred recently the author was able to convince the purchaser that the type of lens in question would give very fine results if used with a suitable colour screen instead of in the manner suggested by reading the maker's too optimistic description. Probably one of the best screens to use for such lenses is one of the tricolour green type. The author uses the one made by Wratten, along with the Allochrome plate by the same maker. Such a plate as this (sensitive to yellow green) is preferable for this purpose to a panchromatic plate, as the red sensitiveness of the latter is no advantage—rather the reverse.

(d) *The Relationship of Aperture and Magnification.*—With the author's arrangement of condensers, the beam of light entering the vertical illuminator is rather larger than the largest back lens of any objective he has; it is therefore necessary to use the iris diaphragm on the illuminator (D, Fig. 3). His practice is to cut down as little as possible. Generally he leaves the back combination 5-6ths full; it is only on rare occasions that he reduces below this. If the aperture is cut down much more than this, any surface irregularities due to scratches are shown up in a very prominent manner, owing to diffraction bands. For this reason, of course, it is well to reduce the aperture to less than 5-6ths when any relief effects in the structure have to be emphasised. The effect of gradually reducing the aperture of an objective has probably been studied mostly from the point of view of the higher power objectives. The bad effect produced on the images given by such lenses owing to such reduction is probably well known, though the fact that photomicrographs of metals showing diffraction effects caused by such reduction are still published shows that this bad effect is not always sufficiently appreciated. With lower power lenses the effects are not so marked metallurgically, since, generally, the photographs taken with such lenses give a general view over a large field, and are not intended to show fine detail. In addition to this, such low power lenses (*e.g.*, 1 in. or 2-3rds) have in general a higher ratio of N.A. to magnification than the higher powers. For example, the N.A. of the lenses mentioned above is generally between .24 and .30, and they are used for photographs at, say, 50 to 150 diameters. On the other hand, twelfths used at 1,000 and 1,500 diameters have at the most 1.4 N.A., and frequently only 1.2 to 1.3. Consequently there is more latitude with the stopping down of low power lenses, but still it should be remembered that with these lenses diffraction effects are produced, and there is a limit to the reduction of the aperture beyond which it is not advisable to go. By suitable stopping down, however, one can often, with these low powers, obtain a larger field sharp all over—frequently of great importance.

Under present conditions nothing is gained by photographing at any higher magnifications than about 1,500; with the present maximum aperture available (N.A. 1.40), all detail which can be shown is visible at this magnification. Any higher magnification is of the nature of an enlargement, and can be obtained equally as well by photographing at this magnification ($\times$ 1,500), and enlarging from the negative, as by taking the negative direct at the higher magnification. There is no doubt that for many metallurgical purposes a higher magnification, coupled with greater resolving power, would be of great value. This could be obtained either by using light of very short wave-length, with its attendant difficulties of focussing, and also the necessity of special lenses capable of transmitting light of such short wave-length or by increasing the aperture of the objective. With regard to the latter, the author believes the firm of Zeiss produced some years ago a 2.5 mm. objective working at about N.A. 1.65. This objective had a front of flint glass, and used as immersion fluid monobromide of naphthaline. Its use, however, for transparent work was attended with great difficulties and expense, inasmuch as the slip and cover glass had

to be of flint glass. With metallurgical work, however, these difficulties would not occur, and it seems to the author that such a lens would be of value in elucidating some of the finer structures met with in metals. If such a lens could be made it should preferably be apochromatic, but, if not, it might be advisable to correct it for blue violet, as the "preferred colour," in order that the highest resolving power could be obtained photographically.

It is obvious that at the highest powers the apochromatic lens has a much greater resolving power than the semi-apochromatic of the same aperture, owing to its capability of working with blue violet light. It should be emphasised that, other things being equal, using light of wave-length 4,500 A.U. instead of 5,500 A.U. is equivalent in its effects to increasing the N.A. approximately 25 per cent.

(e) *Exposure and Vibration Effects.*—In metallurgical photomicroscopes for use in works' laboratories it is very important that the exposure required, especially with high magnifications, should be as short as possible in order to avoid the effects of unavoidable vibrations. For such purposes an intense illuminant is required, and such lamps evolve a very considerable amount of heat, which may easily cause trouble with the cement used in the various combinations of the objective. It is very necessary in such cases that an adequate cooling trough be placed in the beam of light before it reaches the microscope. The heat evolved also causes trouble owing to the expansion effects produced in different parts of the microscope and camera.

Even when the exposures are comparatively short (*e.g.*, a few seconds), they still give plenty of time in the case of the higher powers for vibration to have considerable effect. The author has, however, been able to overcome this completely by swinging the whole photomicroscope on springs, as shown in Fig. 7. It will be noticed that the author's camera is vertical. This position has several advantages from a works' point of view; obviously it occupies less floor space than the horizontal pattern, and is probably more easily swung than the latter. It may be mentioned that, with the suspension system used, photographs at 1,000 and 1,500 diameters were successfully taken, although the laboratory was within 50 yards of four 8-ton steam hammers, and also adjoined three sets of railway lines running into the works.

(f) *Low Power Photography.*—It is frequently desirable to be able to reproduce at low magnifications fairly large areas under vertical illumination. With ordinary low power objectives (*e.g.*, 2 in. or 3 in.), it is possible to take photographs at, say, 20 or 30 diameters, but in general the field is only small, about $\frac{1}{8}$ in. or $\frac{1}{16}$ in. diameter. If attempts are made to get a larger field, trouble is at once experienced with the illumination, and often with the definition falling off. Frequently a very large field is required if the photograph is to serve its purpose, as, for example, with groups of flaws, very coarse structures, and segregated areas.

Some ten or twelve years ago the author devised an arrangement for this purpose, and as he has found it exceedingly useful, he puts it forward in the hope that it may be of use to others. There is nothing really novel in the method, it is a combination of several

ideas, but so far as the author is aware, such an arrangement has not been described before, nor has he heard of any similar apparatus.

For such work the ordinary low power objective is not suitable—its "field" is not big enough. The lens the author uses is the 35 mm. projection lens made by Zeiss, though probably equally good results could be obtained with some of the very short focus photographic lenses made by various opticians. As illuminator he uses a piece of microscopic cover glass $1\frac{7}{8}$ in. × $1\frac{1}{4}$ in., mounted in a light brass frame which fits on to the objective. The frame is pivoted, allowing the illumination to be adjusted to a nicety. This disc is used between the objective and the section.

If one is using an enlarging lantern or a projection lantern, then, in order to get satisfactory lighting, as is well known, the condenser must be close to the negative or slide and must focus the illuminant on the projection lens. The same principle is used for photographing metal sections, and the arrangement of condensers is shown diagrammatically in Fig. 8, which shows the 35 mm. lens A attached to

FIG. 8.

Condenser system for low power photography.

the microscope tube and the section B on the stage (the microscope used is the large "Works" model made by Watsons, London, which has a very wide tube—the inner draw tubes are removed for use with this lens). The condenser D forms a considerably enlarged image of the illuminant C (the 500 C.P. Pointolite Lamp) at E close up to the second condenser F, and the latter in turn focusses the image (after reflection at the 45° cover glass reflector G and the surface of the specimen) on the lens A, as indicated roughly by the dotted lines. The condensers used are $2\frac{1}{8}$ in. diameter, and it is possible to illuminate evenly a section about 1 in. diameter; this is more than required, as the field of the lens is only about $\frac{5}{8}$ in. diameter. Fig. 9 shows the apparatus set up, and Figs. 10 and 11 some of the results obtained.

It is obvious that these low powers are of special value where either the structure is very coarse, or where one wishes to show the variation of structure over a fairly large area. For example, Fig. 10 (× 15 diameters) shows far better than a photograph at, say, 100 diameters, the structure of the sample of overheated steel from which it was taken. Fig. 11 (× 15 diameters) illustrates another type of photograph for which the ordinary microscopic objective would be quite useless; this shows the size and distribution of carbon in an unsound segregated area. This actual example is rather unique, showing, as it does, high and low carbon areas in close proximity.

With the author's camera and microscope, magnifications ranging from 9 to 23 can be obtained, but with a longer camera it would be quite possible to reach 30 or 40 diameters. As mentioned above, the tube of the author's microscope is very wide and comparatively short (2 in. diameter and $4\frac{3}{8}$ in. long), and this enables one to use practically the full field of the 35 mm. lens; with a narrower tube, of course, part of the field would be cut off. In such cases one may do without the microscope and mount the lens on a small fitting (with either spiral or rackwork focussing) on the front of the camera. In one or two cases the author has done this, and has succeeded in obtaining a $6\frac{1}{2}$ in. circle at 9 diameters (*i.e.*, a field of .72 in.). The definition in this case was not quite perfect round the edge, but it was sufficiently good for the purpose.

It may not be out of place to mention that when taking a photomicrograph without using an eye-piece it is necessary to avoid reflection from any metallic surface inside the microscope tube. The latter should be coated with a dull black varnish, but it is generally advisable to put in a lining of black cloth. Such a lining

FIG. 12.

Illuminating system for lowest powers (up to about $\times 5$).

can be easily made by gumming a piece of black cloth of the required size on to a similar piece of fairly stiff paper, then rolling into a cylinder (cloth inside), which can be slid into the microscope tube.

For still lower powers one may use a photographic lens of 3 in. to 5 in. focus; the one used by the author is a $5\frac{1}{2}$ in. Holostigmat by Watson, and with this he can reproduce from natural size up to about 4 diameters. In this case a different system of illumination is employed. For the 45° reflector a thin lantern slide cover glass is used. (It is possible to obtain thin microscopic cover glasses in sizes up to $4\frac{1}{4}$ in. $\times$ $3\frac{1}{4}$ in., but such glasses are very fragile.) A large piece of ground glass is mounted close to the section as shown at A in Fig. 12, and the condenser B throws a parallel or slightly divergent beam of light on this. The idea is to produce an evenly illuminated disc of light on the ground glass, and the light from this is reflected on to the section by the 45° reflector C. Such low magnifications are especially valuable with sections etched with one of the "copper" reagents (such as Stead's, Rosenhain's, or Le Chatelier's), which require a low magnification as a general rule. Fig. 13 is an example of this—it represents a section ($\times 4$ diameters) from a small sample ingot (taken for analytical purposes from an

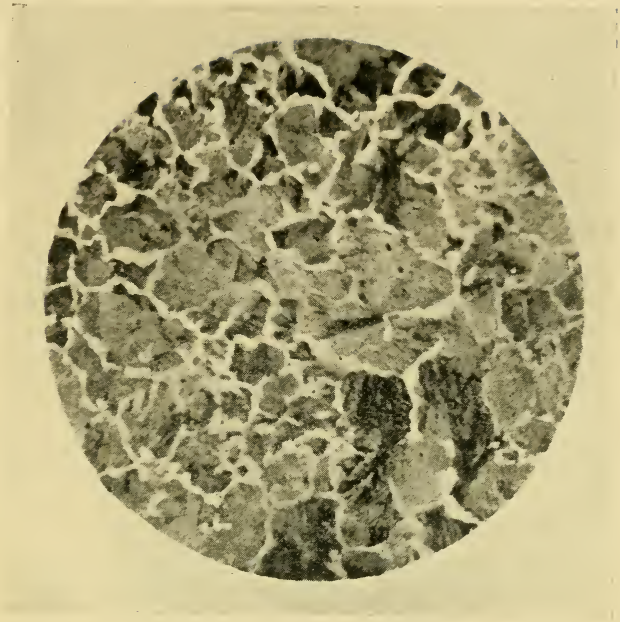


FIG. 4.
Ferrite and Pearlite, using good disc.
× 100.

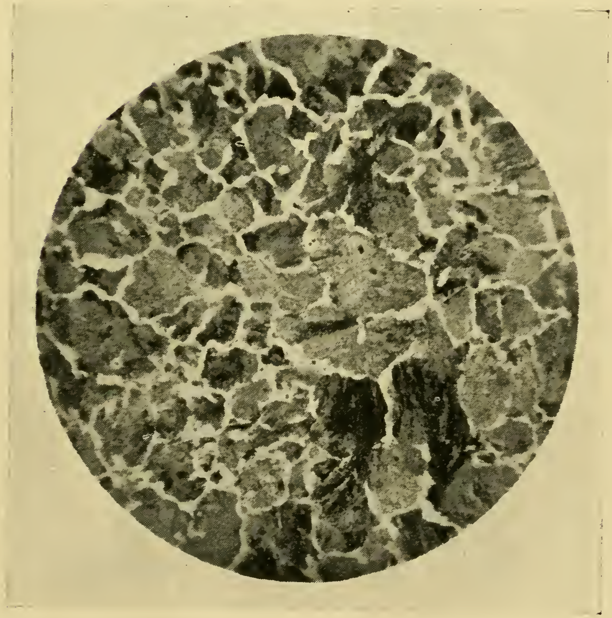


FIG. 5.
Same field as No. 4, but taken
with bad disc. × 100.

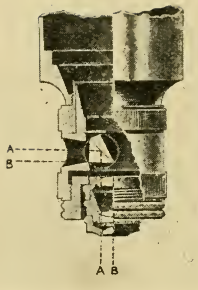


FIG. 6.

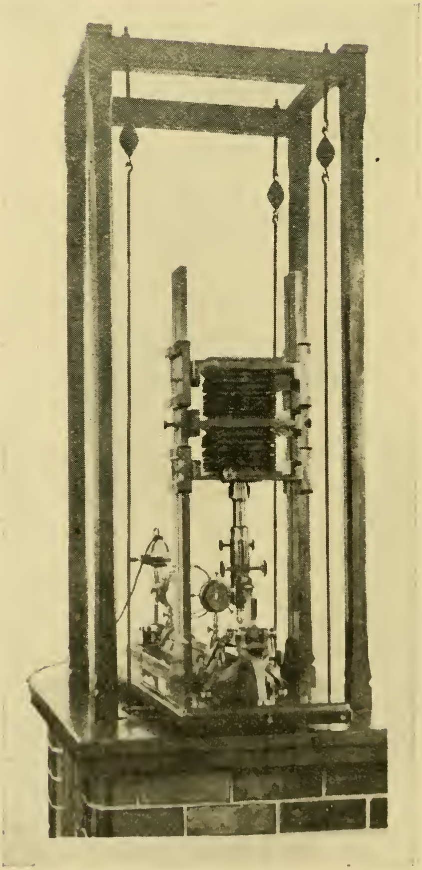


FIG. 7.

Photomicroscope showing spring suspension.

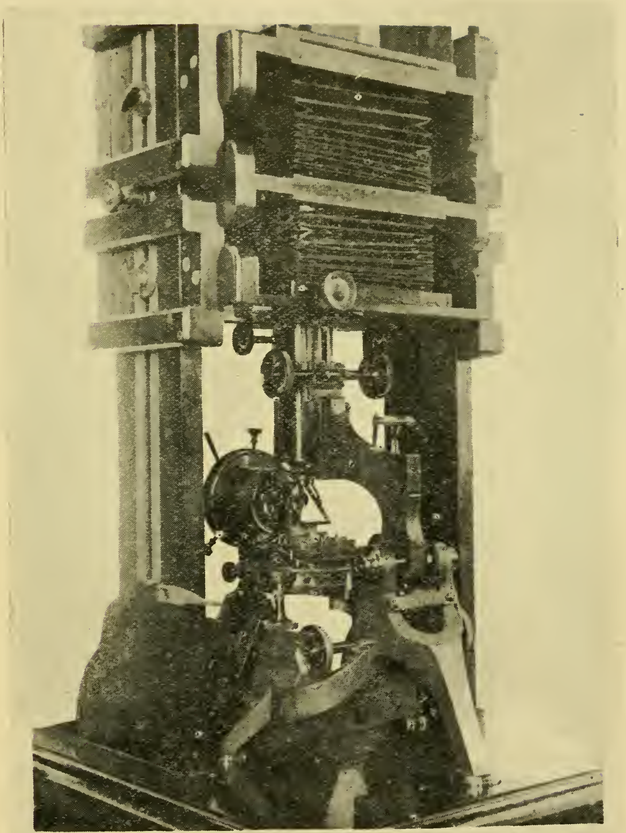


FIG. 9.

Microscope and condenser arranged for low power photography.

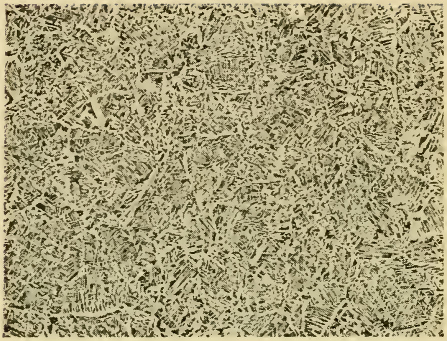


FIG. 10.

Overheated Mild Steel, × 15 diam.

(Reproduced half size—*i.e.*, × $7\frac{1}{2}$ diam.)

FIG. 11.

Segregated Core in Mild Steel Bar × 15 diam.

(Reproduced half size—*i.e.*, × $7\frac{1}{2}$ diam.)

FIG. 13.

Chill crystals in small steel ingot (etched cupric reagent), ×4.

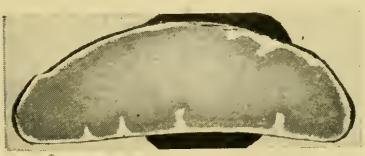
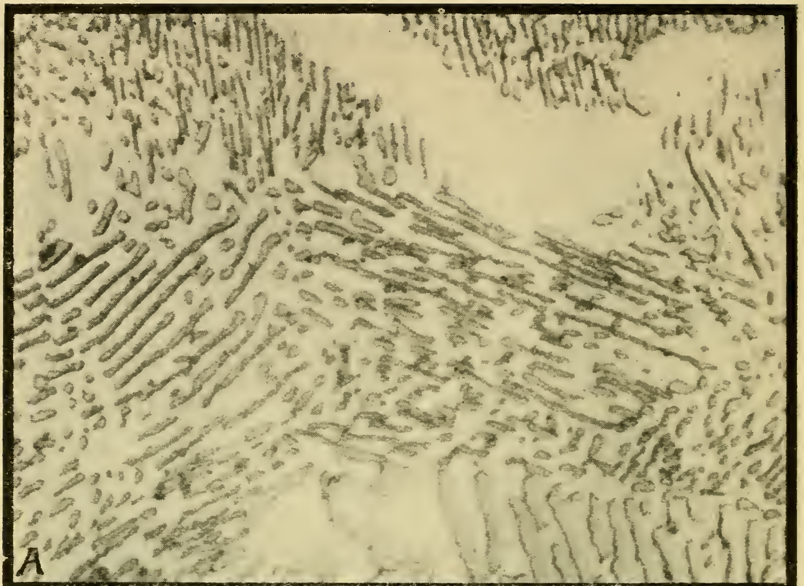
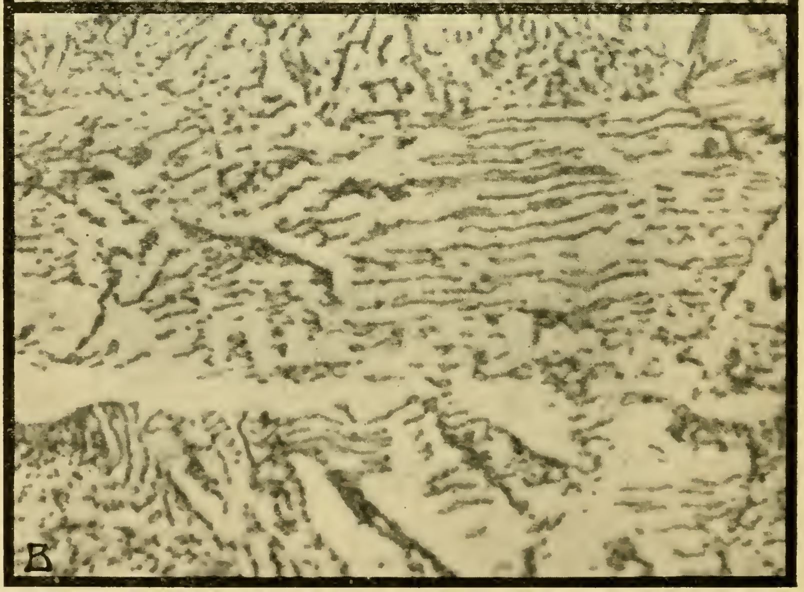


FIG. 14.

Section of Burnt File Blank showing
decarburisation, × 3.
(Reproduced half size).


A


B

A.—Laminated Pearlite and Ferrite.—× 3,500 reduced to 3,000 Zeiss 2 m/m. apochromat. N.A. 1.4., nonochromatic blue light. (Negative × 1,000 and enlarged.)

B.—Pearlite (finer than A) and Ferrite.—× 3,500 reduced to 3,000. Watson 2 m/m. "Holos" N.A. 1.35, yellow green light. (Negative × 1,400 and enlarged.)

electric furnace), and shows the development of long chill crystals. Fig. 14 (from a file blank burnt in forging) was also taken by this method, and shows ($\times 3$ diameters) the decarburisation formed both in the skin and round the cracks.

A method of illumination similar to the last one was described by F. B. Foley in "Metallurgical and Chemical Engineering" (August 1st, 1919). He used it for low power photomicrographs (at about 7 diameters). For this purpose, however, the author prefers the arrangement shown in Fig. 8, as it gives better detail at these magnifications.

In conclusion, the author wishes to thank the Directors of Messrs. Brown Bayley's Steel Works, Ltd. (and in particular Mr. H. Brearley) for permission to publish the photographs accompanying this paper, and also to Messrs. F. S. and W. H. Nicholds (members of the Laboratory Staff) for their assistance in preparing the photographs and diagrams.

METALLURGICAL MICROSCOPES AND THEIR DEVELOPMENT.

By Leslie Aitchison, D. Met., B.Sc., A.I.C., and F. Atkinson.

It is assumed that the primary function of this symposium is to bring out the present position in regard to microscopes and also to elicit those improvements which could well be introduced into microscopes with a view to improving the instruments, making them more convenient to employ, and also elaborating the uses to which they can be put. The present notes are written from the point of view of the metallurgist, and primarily from that of the working metallurgist, to whom the microscope is of constant value and usefulness. No attempt is made to discuss the questions from the optician's standpoint, but rather to indicate the needs of the metallurgist in the hopes that the optician and miscroscope manufacturer will be able to meet more and more of these requirements.

In saying anything of modern microscopes it is difficult to avoid constant reference to the products of the Continental makers, and to make comparisons between their microscopes and those produced in this country. This has reached the stage at which comparisons usually take the form of stating how near the British article approaches to the Continental. The position will not be really satisfactory until the reverse of this position is the true one, i.e., until the British article is compared with the Continental on the basis of the superiority of the former and not upon its inferiority.

Speaking as users of microscopes and microscopic outfits, one of the first points that requires attention is the more prompt incorporation in the instrument of those details and fittings which make the use of a microscope less laborious. The Continental makers were always ready to adopt and to incorporate these details, and it would be of great assistance if the British manufacturers would do the same. For instance, the Continental makers would supply a stage micrometer in metal (a great improvement upon those made in glass), marked in tenths and hundredths of a millimetre. The British manufacturer has up to the present given us one marked only in tenths of a millimetre.

A similar matter, and one that causes a good deal of trouble, is the lack, upon photomicrographic outfits, of a really good, reliable and workable fine focussing arrangement which can be operated from the camera end. This objection applies to *all* microphotographic outfits, British and Continental, as none of those made give real satisfaction. For metallurgical work photomicrography is of great importance, and if photographs are to be taken at high powers, *e.g.*, up to 1,000 diameters, the focussing apparatus is of vital importance. Those at present manufactured do not work really well, and cause a great deal of irritation to the operator.

Connected with the photomicrographic outfit is the trouble which is experienced because of the lack of adequate devices for the prevention of vibration of the apparatus. The greatest proportion of metallurgical photomicrography has to be done in works. Such places are always subject to a fair amount of vibration, which is usually transmitted in a greater or less degree to the apparatus. This almost renders high power photography of the higher order impossible. The problem of vibration is not new, and various efforts have been made to solve it by the makers, but up to the present these efforts have not proved at all successful. The existence of the vibration is one of the factors which limits the development of higher powers in industrial microphotography.

Photomicrography is not possible at all unless the source of light is good and reliable. The arc lamp is not good for photography. It is too uncertain. It is very prone to flicker, and also to give a wandering source. Further than that, it requires a good deal of attention—replacing and adjusting of carbons—whilst it also usually involves the use of a mechanical device for keeping the arc in its correct situation. Lime-light does not suffer from these defects, but it presents the other difficulty, namely, that it is not sufficiently intense to provide a good illumination at high powers, and therefore to allow of short exposures. The specially designed sources of illumination, such as the Pointolite, are distinctly better, and it is considered that this is the form of illumination which will best repay development.

It is obvious, of course, that the improvements indicated above are of little value unless they are accompanied by excellence in the more purely optical parts of the outfit. The critical part of the microscope is undoubtedly the combination of the lenses, and it is probably in this part of the equipment that the standard Continental makes are most missed. There are numerous points about the lenses which could be considered, but one of them can be selected as typical. This is the production of a flat field. In this respect the Continental outfits showed a great superiority, as they permitted photographs to be obtained perfectly sharp at really low magnification (10). This was of immense importance in the study of cast metals and in watching the persistence of the primary crystallisation of a metal through all the subsequent stages of working and treatment. Unfortunately no such good results can be obtained with the usual British lenses.

The usual range of magnification of the modern microscope ends at about 1,500 diameters—particularly in so far as photography is concerned. Unfortunately there are many things which this magnification does not reveal, and which the metallurgist would be glad to investigate. It seems that it might be useful to indicate a few of the points which the invention of a " metallurgical ultra-microscope " might be expected to make plain.

Several such points arise in connection with tempered steel, and although it is not possible to make their significance entirely plain without introducing a good deal of matter apart from microscopical, they may be taken as typical problems. As is well known, hardened steel consists essentially of a solid solution of iron carbide in iron. If this solution be tempered, a certain change takes place in it, which is reflected in the mechanical properties of the steel, which becomes softer and tougher. This change is usually (and probably quite correctly)

ascribed to the splitting up of the solid solution, the iron carbide being precipitated in a fine state of division throughout the solvent iron. That this explanation is correct in its outline is more than probable, and when the tempering has proceeded to something like completion the presence of the carbide is easily detected. The early stages of the decomposition are practically incapable of observation with the present microscopic means which are available, but this is the portion of the process which is of the greatest interest and importance. It is almost impossible at the present time to say at what temperature the decomposition of the solid solution commences or how it proceeds. In many carbon steels the maximum stress, which in the ordinary way is supposed to decrease when the tempering temperature increases, actually increases at tempering temperatures near to 400° C. Typical results are:—

TABLE I.

Steel	Heat Treatment	Max. Stress tons/sq. inch.
0.3% carbon	Quenched 850°C. ... temp. 15°C.	50.5
	,, ,, ... ,, 100°C.	49.6
	,, ,, ... ,, 200°C.	49.4
	,, ,, ... ,, 300°C.	47.1
	,, ,, ... ,, 400°C.	50.1
	,, ,, ... ,, 500°C.	46.8

It is quite likely that if the constitutional changes going on within the steel could be examined microscopically, and a better idea of these changes formulated, the explanation of the peculiar happenings would be found. This would require a very high power—something probably of the order of ten times as great as the present powers.

Similiar problems arise in connection with the tempering of the alloy steels. In the nickel chromium steels, for instance, a property known as temper brittleness is shown by steels which cool slowly from or through a certain range of temperature, *e.g.*, 425° C. to 550° C. In all other respects the mechanical properties of the steels are the same whether cooled quickly or slowly. The effect of different methods of cooling from this temperature upon the toughness is shown in Table 2.

It is inconceivable that there is no difference at all in the constitution of the two steels, but the present microscopic methods fail entirely to detect the difference (see Figs. 1 and 2). It is possible that higher powers would make the detection possible. The same powers might also give an explanation of the peculiar impact values which are obtained from the alloy steels by tempering at comparatively low temperature, *e.g.*, 150° to 350° C. The accompanying curve (Fig. 3) shows the values which are customarily obtained, and in addition shows

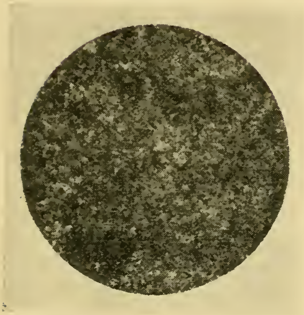


FIG. 1.

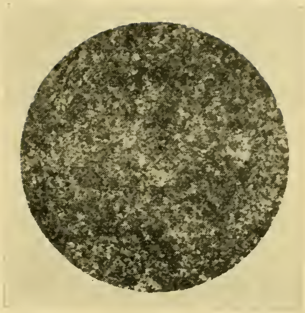


FIG. 2.

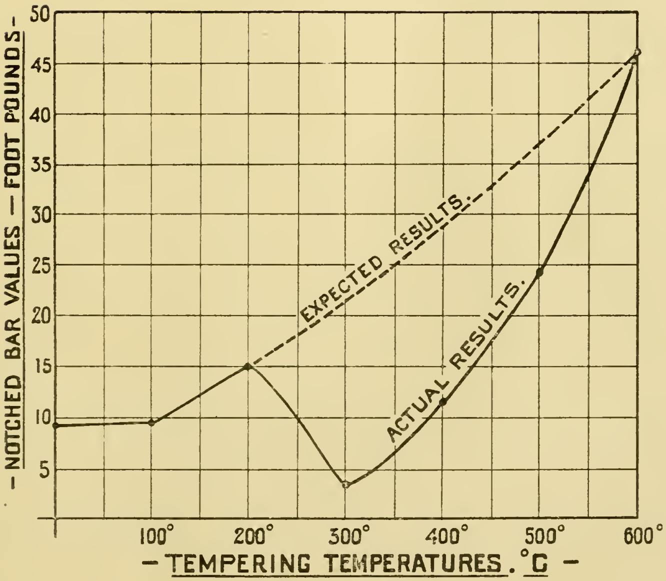


FIG. 3.

the form of the curve which might reasonably be expected. Here again there is surely some constitutional alteration taking place, and it might reasonably be hoped that a sufficiently high powered Microscope would reveal it.

The theory which has probably had as much effect as any other upon recent scientific metallurgy is that known as the "amorphous cement" theory. This theory postulates the existence, between the crystals of a metal, of a thin layer of amorphous material which both

TABLE 2.

Tempering Temperature.	Notched bar value on tempered specimens.	
	Cooled in air after tempering.	Cooled in water after tempering.
400°C.	8	8
500°C.	18	18
550°C.	7	30
600°C.	8	41
650°C.	8	53

separates and binds together the individual crystals. The properties of this amorphous metal are necessarily different from those of the crystals which it surrounds. The evidence for the existence of this layer is largely circumstantial, and though the evidence is powerful it would be decidedly stronger if the cement could actually be revealed. If a power of 10,000 failed to produce any further evidence of its existence it would seem difficult to imagine that it is really there.

Duralumin is a metal which has distinctly peculiar properties. If duralumin be quenched in water from a suitable temperature it is soft at first, but after standing for a time, e.g., 24 hours, the metal becomes quite hard. This change of properties is bound to be accompanied by some change of constitution, and a possible explanation of this change has recently been put forward by Dr. Jeffries. It seems certain, however, that the application of higher powers of microscopic examination would help materially in the investigation of this problem.

PHOTOMICROGRAPHS OF STEEL AND IRON SECTIONS AT HIGH MAGNIFICATION.

By Sir Robert Hadfield, Bart., D.Sc., D.Met., F.R.S., and Mr. T. G. Elliot, F.I.C.

Owing to the importance of the study of Microstructure much attention has been given to this subject since the days when the late Dr. H. C. Sorby, F.R.S., of Sheffield, originated, in 1857, this method of examining structures of various materials, including Iron and Steel. Indeed, one of the most striking features of the progress of Metallurgy in recent years is the great development of the use of microscopical methods of investigation. We submit some photomicros, Figs. 1 and 2, Plate A, representing some of the early work of Dr. Sorby at 9 magnifications. We also submit as a comparison, and in order to demonstrate the great advance in Metallography, Photomicrographs Figs. 3 to 25 showing later work of the writers of this Paper, in which magnifications are dealt with of 100 and up to no less than 8,000.

In carrying out this work, our best thanks are due to Mr. H. Wrighton, B.Met. for the assistance he has rendered and for the care and skill he has exercised in preparing the Photomicrographs accompanying our Paper.

One of us well remembers his conversations with Dr. Sorby regarding the micro study of his own early specimens of Manganese Steel, in 1883-1887. Dr. Sorby never turned away the youngest enquirer, and he little imagined when first describing his method in 1857 what an important aid this would eventually prove to Metallurgy. This is another instance of the great value to the Metallurgist of original work by the pure Scientist. Next to Sorby, this important branch of investigation owes more for its development to Arnold and Osmond than any others. It has been further advanced by Sauveur, Stead, Le Chatelier, Carpenter, Howe, Martens, Robin, Rosenhain, and many others.

Sorby bequeathed £15,000 to the Royal Society for the establishment of a Fellowship for the carrying on of original Scientific Research, the object specified being "to promote the discovery of new facts rather than the teaching of what is known," and stated that as far as possible the Researches should be carried out at the University of his own native City, Sheffield. To this Englishman, Sorby, the whole world has fully and freely given the credit of originating this important form of research which enables the structure of Iron and

its Alloys, including in that term the material generically known as "Steel," to be examined and understood in a manner which was before not possible. "Steel" is a wide term and to-day covers material which is practically pure Iron, for example, products containing 99.9 per cent. of Iron which offer high resistance to corrosion and oxidation and containing practically no Carbon, up to the material used for wortle or drawing plates which contain even more than 2 per cent. of Carbon.

Twenty-five years ago there were scarcely half-a-dozen Steel Works in the country which could lay claim to the possession of a Microscope suitable for metallographical examination. At the present time it may be safely said that no steel works of any size is without one. Nor is the use of the Microscope confined to the examination of Iron and Steel sections, for those engaged in the investigation of non-ferrous metals and alloys find its aid equally useful.

The history of Metallography, short as it is, is beyond the scope of the present paper. Naturally such history to be complete would record the improvements which have taken place in the construction of Lenses for metallographic work. One of the most important of these was the introduction of the Apochromatic Objective by means of which increased resolution was obtained, an absolute necessity for successful high power photomicrography. Unfortunately, as this Country had occasion to find out on the outbreak of War, the making of these objectives has in the past been largely in foreign hands. Steps are being taken to remedy this, and there is every reason to hope that here, as in other directions, in future, we shall be rendered entirely independent of the foreigner.

Great as have been the advances made in the microscopical examination of Iron and Steel, there still remains a wide field for exploration; for example, as regards methods which will enable increased magnifications to be obtained. It is wonderful what can be accomplished by the aid of the human eye alone, and even to-day the finest quality of crucible cast steel is, in its ingot form, first packed or sorted over in this manner. It is stated that an experienced workman can, by the eye, detect from the appearance of the fracture differences as small as .05 per cent. to .10 per cent. of Carbon. No doubt for many purposes an ordinary strong magnifying glass will tell much and more than the unaided eye can do, but when it is desired to reveal structures minutely, then the microscope is called in with great advantage. Magnifications of 10 or less, upwards to 1,000 or 1,500 are those most commonly used in metallography. Photomicrographs of larger magnifications than 1,500 have been rarely published. The Authors have, however, carried out experiments in order to obtain photographs of 5,000 and even 8,000 magnification, which may be of interest to this Society.

The very fine structures met with in alloy steels have made it desirable and induced the Authors to prepare in their research photomicrographs at higher magnifications than have hitherto been obtained. With great care and attention to necessary details, particulars of which are described in this Paper, we have been able to

obtain photographs of Iron and Steel sections at the high magnification of 8,000 diameters. To give an idea of what this means, it may be mentioned that the diameter of the actual field shown in a $3\frac{1}{4}''$ circle photograph at this magnification is only .00041″ or 1/2460″. The actual area of this field examined is .00000013 square inches. The polished section under micro-examination is usually about $\frac{1}{4}$ in. square. If the whole of this area were magnified 8,000 times it would yield a square about 55 yards by 55 yards, occupying an area of approximately 3,000 square yards, that is to say, not far away from three-quarters of an acre.

As is well known, the modern Microscope consists of two systems of lenses, the objective and the eye-piece. The objective gives an enlarged image of the object, and the eye-piece further magnifies this image. The high power photomicrographs given in this Paper are simply high magnifications by means of the eye-piece and extra camera extension of the image given by a 2 mm. objective, or in the case of the 8,000 magnifications by a 1.5 mm. objective. Whatever may be the quality of the image given by the objective—for example, as regards resolution—that quality is reproduced in the magnified image of the eye-piece. Thus, if the objective gives a blurred image, the blur is simply magnified. In other words, it is just as though a lantern slide were projected on the screen; if the slide is a good one we get a good picture, but if bad the picture will be no better because it is magnified. The essential aim, therefore, is to get a very clearly resolved image. This needs a special quality or virtue in the objective, and this virtue is called its resolving power.

For photomicrography at high magnifications, it is specially essential that an objective of high resolving power should be used. The effect of magnification without resolution is well illustrated by Figs. 3, 4 and 5 on Plate B. These photographs are all at 600 magnifications, but taken by objectives of low, medium, and high power respectively. In No. 3 the dark ground mass is left unresolved. No. 4 shows some resolution of this dark ground mass, but in No. 5 it is practically completely resolved into its two constituents, Ferrite and Cementite in lamellar form. In the course of a search for a really good 2 mm. oil immersion objective, for photomicrographic research, we found that results obtainable with a moderate Achromat, compared with those obtained with a good Apochromat, showed differences at least as great as is illustrated in Figs. 4 and 5.

An illustration of the microstructure of an Annealed Alloy steel, containing .84 per cent. Carbon and 1.12 per cent. Chromium, is shown at four different magnifications in Figs. 6, 7, 8, and 9 on Plate C. Although the resolution of the structure is the same in Figs. 7 and 8, because the same objective was used in each case, the effect of the increased magnification is to show in a striking manner the alternate white and dark constituents of the lamellar pearlite. This effect is further emphasised in a photograph of the same section at 8,000 magnifications, shown in Fig. 9. There is no doubt that this magnification taxed the lens somewhat beyond its capacity; however, the photograph is certainly a good one and worth including, if only to show the limit obtainable with the apparatus available at the present time.

Photomicrographs of Diatoms at 5,000 magnifications and over, taken by transmitted light, have been published; but so far as we are aware steel sections at such a high magnification have not been available. This may be easily accounted for by the difficulties in the way. Although, unfortunately, we are unable to indicate an easy path by which these difficulties may be avoided, we propose to show the means by which we endeavour to overcome them.

We have already laid stress on the need for an objective of high resolving power capable of giving good definition when combined with a properly compensated eyepiece of high magnifying power.

Probably the next most essential point is that the specimen to be photographed be properly etched. Deep etching is fatal; it causes pits and furrows in the surface of the piece which extend beyond the range of depth of focus, which with a high power objective, is naturally very limited. Therefore the most delicate etching is necessary, and this we find is usually best obtained with 5 per cent. Picric Acid in Alcohol.

The illumination of the specimen for photography is the next subject for attention. For high power photography the lighting should be as intense as possible. We use a 20 ampere arc lamp of the hand fed type, and this is found preferable to one mechanically fed. It is simple, has no mechanism to get out of order, and the carbons are not liable to re-adjustment at the critical moment, just when the plate is being exposed. Moreover, mechanically fed carbons are never so firm and free from vibration as those of the hand fed types. Alternating current at about 70 volts can be used with perfect success on a 20 ampere hand fed lamp, if cored carbons are used. This is a point on which emphasis should be laid, for the makers of our apparatus have always laid stress on the necessity for direct current for photomicrographic work. Tungsten Arc and Mercury Vapour Lamps have been more recently introduced for photomicrographic work, but we have had no opportunity of testing them.

The vertical illuminator attached to the Microscope should be a plain glass disc. We find a prism unsatisfactory for this work. The light should be focussed on the diaphragm of the vertical illuminator, and of course it must be perfectly central with the Microscope and the camera.

The iris diaphragm of the illuminator should only be closed as much as is necessary to get sufficient of the field sharp. Further closing of the diaphragm not only interferes with the resolution, but produces false images. An example of this effect is shown in Figs. 10 and 11, Plate D. Fig. 10 illustrates the result produced by closing the diaphragm too much, and Fig. 11 shows a correct image obtained by proper adjustment.

The diaphragm in the condenser system should be closed so that only the area to be photographed is illuminated.

For apochromatic objectives, a blue screen as a light filter should be used, and ordinary photographic plates. The specimen is focussed first of all on the ground glass screen of the camera, and finally adjusted

with the clear glass screen and the aid of the focussing magnifier. There is one point that has not been mentioned, which is quite obvious, and that is the necessity that the mounting of the whole photomicrographic apparatus should be perfectly rigid and free from vibration.

We have selected a few photomicrographs in order to show the effect of increasing magnifications on the same section, and also to illustrate well-known types of microstructure at high magnifications. The objectives used in obtaining photographs at 1,500 and over are stated on the plates.

The photographs on plates A, B, C and D have already been dealt with in the text.

PLATE E. — Figs. 12, 13, 14 and 15, show the microstructure of a Nickel Chromium Alloy Steel in two different conditions. Even at 1,500 magnifications the structure is seen to be very fine and close textured ; it is rather more clearly defined at 5,000 magnifications, but a structure of this kind is very difficult to photograph owing to the want of contrast obtained even with the most careful etching.

PLATE F. — Figs. 16, 17, 18 and 19 show the structure of Grey Cast Iron. The black constituent is Graphite, and the ground mass Pearlite. The four photographs on this plate illustrate very strikingly the advantage of higher magnifications in order to see clearly the details of a fine Pearlitic structure.

An additional photograph (Fig. 19a) is given on Plate F, which has been obtained by making an enlargement of the negative from which Fig. 18 was obtained. The enlargement has been so adjusted that its magnification is 5,000 ; a comparison is therefore obtainable with that of Fig. 19, which has been obtained by the direct method. There does not appear to be much to choose between the two Photographs in this instance, but in the case of more complicated subjects such as those illustrated in Figs. 20 to 22 on Plate G, the direct method of photomicrography, although very much more difficult than the indirect one of enlargement, is far preferable to the latter because the choice of field to be photographed is made at high magnification—an important advantage.

PLATE G. — Figs. 20, 21 and 22. Photographs 20 and 21 show the microstructure of a Carbon-Chromium steel in two different conditions, magnified 8,000 diameters. The former is a Sorbitic Pearlite structure, and the latter consists of Martensite and Troostite (black areas). — Fig. 22 shows the microstructure of a quenched Carbon steel at 8,000 magnifications, and is Troosto-Martensite.

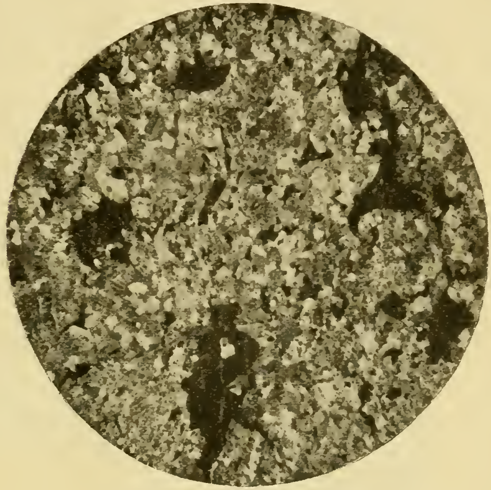
PLATE H. — Figs. 23, 24 and 25. These photographs show the microstructure at 5,000 magnifications of a steel containing 1.41 per cent. Carbon in three different conditions. Fig. 23 is a typical Pearlite and Cementite structure ; Fig. 24 a Martensitic structure, and Fig. 25 a structure of mixed Troostite and Cementite.

The value of higher magnification especially as illustrated in Figs. 8, 9 and 19 can be emphasised as a result of this research. These Photographs at higher magnifications show in a striking manner the details of a structure which at lower magnifications are only

PLATE A.

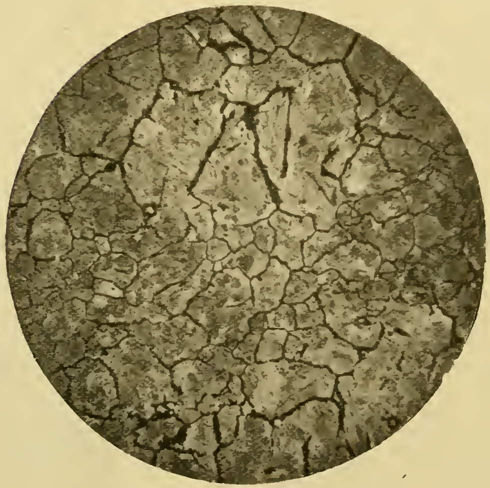
Examples of early Photomicrographs from Sorby's Paper to the Iron and Steel Institute, 1887, "On the Microscopical Structure of Iron and Steel."

FIGURE 1.



Photomicrograph by Sorby.
Magnification 9.
Hammered Bloom Carbon .05%

FIGURE 2.



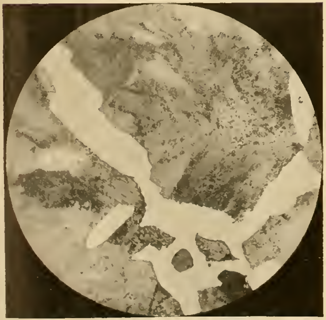
Photomicrograph by Sorby
Magnification 9.
Blister Steel, Longitudinal Section.

PLATE **B.**

FIGURE 3.

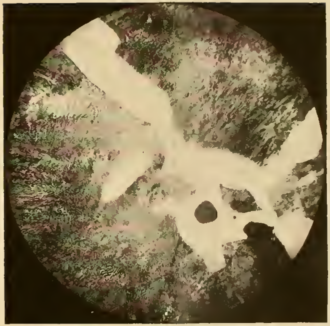
Magnification 600.
12 MM. ACHROMAT.

FIGURE 4.



Magnification 600.
4 MM. ACHROMAT.

FIGURE 5.



Magnification 600.
2 MM. APOCHROMAT.

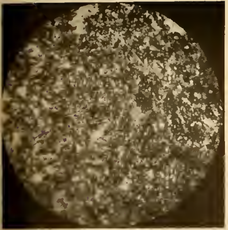
The Steel used in this Experiment had the following composition:

C.	Si.	S.	P.	Mn.
.48	.17	.029	.034	1.00%

Photomicrographs showing the Effect of Magnification without Resolution.

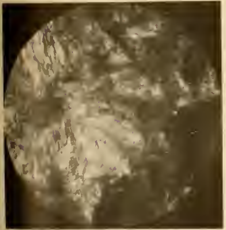
PLATE C

FIGURE 6.



Magnification [illegible]

FIGURE 7



Magnification [illegible]

FIGURE 8.

Magnification [illegible]

FIGURE 9.

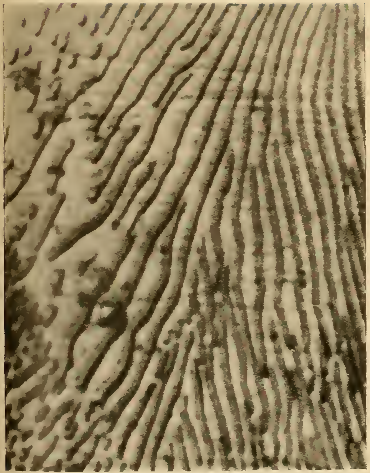
Magnification 8,000

[illegible] STRUCTURE OF [illegible] LAMELLAR AND SORBITIC PEARLITE

The Steel used in this Experiment had the following composition: .84 .30 .45 [illegible] .13

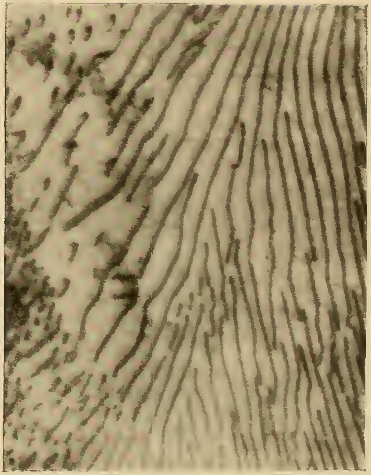
PLATE D.

FIGURE 10.



Magnification 5,000.

FIGURE 11.

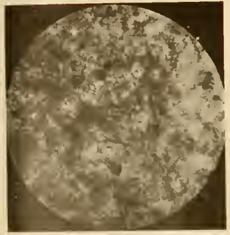


Magnification 5,000.

Photomicrographs showing, respectively, the effect of Incorrect and Correct use of the Iris Diaphragm.

PLATE **E.**

FIGURE 12.



Magnification [illegible]

ANNEALED

FIGURE 13.

Magnification [illegible]

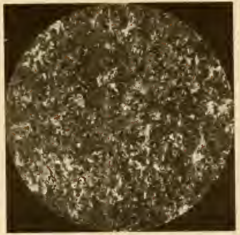
ANNEALED

STRUCTURE OF FINE [illegible] AND SORBITIC PEARLITE

The steel used in this [illegible] had the following composition

[illegible]

FIGURE 14



Magnification [illegible]

Quenched and Tempered

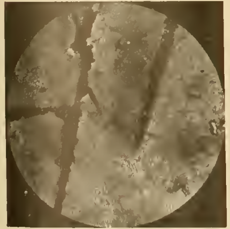
FIGURE 15

Magnification [illegible]

Quenched and Tempered

STRUCTURE OF TROOSTITE AND SORBITE

PLATE F.



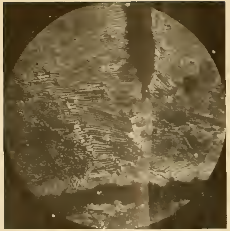


FIGURE 19

Magnification 5,000.

FIGURE 19a.

ENLARGEMENT FROM NEGATIVE OF PHOTOGRAPH

PLATE G.

FIGURE 20.

Magnification 8,000.
1.5 MM. APOCHROMAT
SORBITE.
Quenched and Tempered.
The steel used in this Experiment had the following composition

C.	Si.	S.	P.	Mn.	Cr.
.93	.23	.042	.021	.31	2.51%

FIGURE 21.

Magnification 8,000
1.5 MM. APOCHROMAT.
TROOSTO-MARTENSITE
Quenched.

C.	Si.	S.	P.	Mn.	Cr.
.93	.23	.042	.021	.31	2.51%

FIGURE 22.

Magnification 8,000
1.5 MM. APOCHROMAT
MARTENSITE AND TROOSTITE
Quenched.

C.	Si.	Mn.
.90	.27	.29%

PLATE H.

FIGURE 23.

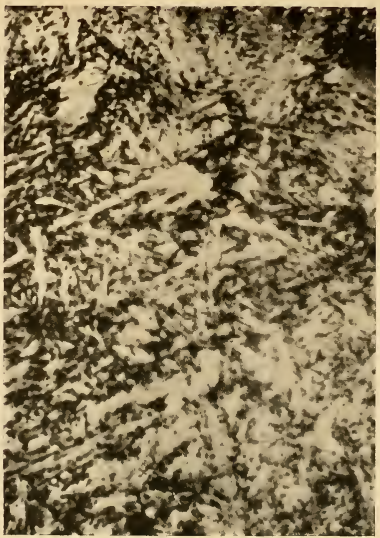
Magnification 5,000

1.5 MM. APOCHROMAT

PEARLITE AND CEMENTITE

Annealed

FIGURE 24.



Magnification 5,000

1.5 MM. APOCHROMAT.

MARTENSITE.

Quenched

The Steel used in the Experiment had the following composition:

C.	Mn.
1.41	.38%

FIGURE 25.

Magnification 5,000

1.5 MM. APOCHROMAT.

TROOSTITE AND CEMENTITE

Quenched and Tempered

very indistinctly seen; at the same time we are quite alive to the fact that they have not led us to any absolutely new discovery in the microstructure of Steel, and it is quite evident that there is an important field open for further investigations in this direction.

During the last few months we have been prosecuting enquiries in different directions with a view to obtaining apparatus which would enable us to attain much higher resolution than has been practicable with that at our disposal. While so far we have not been able to do this, several makers of apparatus and objectives in this Country are working at the problem, which we feel sure will soon be solved.

We have also been specially interested in the possibilities that might lie in the use of Ultra-violet Light for Photomicrography applied to Metal Sections. Who knows what new order of Phenomena may not be brought within our vision by the use of such apparatus. Researches are being made in this new field, and we all hope that such labours will be crowned with success.

In conclusion it is hoped that by presenting these Photomicrographs interest will be aroused in this special subject and that others will press forward investigations from which our general knowledge of the subject will benefit; also that the makers of the necessary Apparatus, whether Microscopes, Lenses or Lighting Appliances, will come forward with new developments which will enable still further fields to be explored in the now Unknown.

THE HIGH-POWER PHOTOMICROGRAPHY OF METALS.

By F. C. Thompson, D.Met., B.Sc. (Lecturer on Metallurgy in the University of Sheffield).

I.—General.

The high-power microscopical examination of metals is a matter of the greatest importance.

As Prof. Abbe has pointed out, however, and this forms practically the whole of the sermon which the author desires to preach, " empty magnification " unaccompanied by a corresponding resolving power is of no service whatever to the metallographer.

As is well known, it is impossible to produce a microscopical rendering of a point other than as a disc of definite dimensions the size of which depends on (1) the numerical aperture of the objective, (2) on the wave-length of the light employed, and (3) on the magnification. The diameter of this spurious disc $D = \frac{m \times \lambda}{2\ N.A.}$ where m is the magnification, λ the wave-length of the light used, and N.A. the numerical aperture of the objective. It will be at once seen that the image becomes less and less sharp as the wave-length of the light increases and as the ratio of the total magnification to that produced by the objective itself is raised.

As shown in Fig. 1, a succession of points may thus, if sufficiently near each other, merge into an apparently continuous line, the true structure of which would never be realised. Sorbite might in this way simulate pearlite. A very beautiful illustration of this effect in a diatom is given by Spitta, " Microscopy," Fig. 3A, Plate I. It will further be evident that a sorbite in which the diameter of the spurious disc exceeds the distance between the carbide globules will appear practically structureless, Fig. 2A, and that pearlite, the distance between the laminæ of which does not exceed this diameter, will lose its structure, Fig. 2B. The matter, therefore, is of very real practical import.

Abbe has shown that in the absence of certain diffraction spectra a line may be duplicated, or even rendered as three. Although in metallurgical work such results are unlikely—they would, for instance, double or treble the fineness of a laminated eutectic—the possibility of such spurious effects at very high magnifications should always be borne in mind.

According to Spitta the limit of magnification to which it is permissible to go with light of wave-length 540 $\mu\mu$ must never exceed 1,000 times the numerical aperture of the objective.

It would thus appear that the best method of approach to the very high magnifications suggested lies at the present time in the use of ultra-violet " light " of very short wave-length. Since glass is opaque to such vibrations, quartz or fused silica must be used as the optical material of all lenses, vertical illuminators, etc. In connection with metallographic work, since the objective acts as its own condenser, and since no slips or cover glasses are required, such a system is much cheaper than it can be when using transmitted

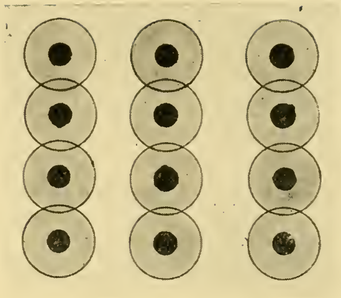
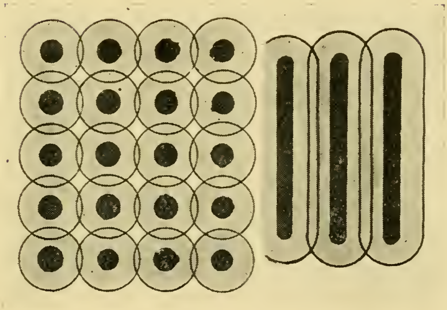


FIG. 1.

Effect of Halo in Producing a Spurious Lamination.



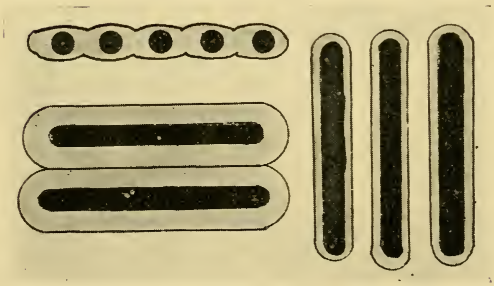
A B

FIG. 2.

Structureless Rendering of Sorbite or Pearlite.

C

A



B

FIG. 3.

Effect of Prism Illuminator.

"light." The lenses in the objective are constructed of fused silica, those of the eye-piece of quartz. A mixture of glycerine and water of the required refractive index is used as an immersion liquid, and focussing is carried out by the use of a fluorescent screen. So far as the author is aware the highest power silica objective so far made is the 1.7 mm. with 1.25 N.A. In virtue, however, of the shortness of the wave-length used, 275 $\mu\mu$, this is equivalent to about 2.5 N.A., using white light, and according to the rule given above could be used for critical work up to 2,500 diams., which would be obtained with, say, a × 15 eye-piece and a camera length of 31 c.m.s. There appears to be a very big field of usefulness for this system in metallographic research work.

II.—The Davidson "Super-Microscope."

The claims made for this instrument in connection with very high magnifications—up to 15,000 diams.—render a consideration of its capabilities germane to this paper. In essence, an image is formed in the usual manner by a microscope objective, which image is then magnified by a second microscope, with or without an eye-piece. Such a procedure demands for the highest magnifications an amplification of the primary image so high that no objective at present made will stand it. In theory the instrument is unsound, and in practice, so far as the author's observations go, the results at high magnifications are very poor. Through the kindness of Sir Robert Hadfield the apparatus was sent to the author some two or three years ago for investigation. Since then the mechanical side has been considerably improved, the optical arrangement remaining, however, unchanged. Quite recently another opportunity has arisen for his observation of the instrument, but his view is unchanged. In the trial two test objects were chosen, one a very fine sorbitic structure in a quenched and tempered tool steel, the other a normalised Bessemer steel with 0.4 per cent. carbon, and 1 per cent. manganese, the pearlite in which was finely laminated. With a magnification of 1,000 diams., using Zeiss lenses and the ordinary apparatus, both objects were easily resolved. At the same magnification, however, the "Super-microscope" failed entirely. The sorbitic material appeared structureless, while in the case of the pearlite only the faintest suggestion of lamination could be detected. At higher magnifications the apparatus is utterly valueless.

The very claim put forward for the instrument that it possesses great depth of focus is in itself an admission that the resolving power is poor, since these two factors vary inversely as each other. Since for the purpose at present under consideration, viz., high magnification of metallic structure, depth of focus is of no importance, while resolution is a matter of prime weight, the remarks previously made are still further substantiated.

For other purposes, as a telescope, or for low power examination of a metallic fracture where great depth of focus is quite necessary, the apparatus probably offers very real advantages. In particular, perhaps, may be mentioned direct measurements from some distance of changes in length, such as are needed in a determination of co-efficient of thermal expansion.

III.—The Reichert Microscope.

This instrument, which is too well known to need description here, has often been regarded as a convenient apparatus for use in those industrial establishments where convenience and rapidity of working are, perhaps, of somewhat greater importance than the very finest definition and resolving power. An investigation recently made by Professor Carl Benedicks and E. Waldow (Jern-Kontorets Annaler, 1918, 537) has shown, however, that far from such being the case, photographs of the very highest quality can be obtained. Several micrographs published by these workers at 1,200 diams. leave little or nothing to be desired. The perfection is further illustrated by an enlargement at 3,500 diams. which constitutes one of the most excellent photomicrographs of steel at such a magnification ever obtained. This magnification, however, has only been used to show what sort of effect is the best at present obtainable, and does not represent one which will yield critical results. Around the globules and laminae of Fe_3C are thick black halos up to and exceeding 0.5 mm. thick.

The authors point out the much lower quality of picture obtained when the prism vertical illuminator is used as compared with that when the plain disc is chosen. This fact, first pointed out by Professor Benedicks himself, is one of prime importance in connection with high power microscopy. Since in one direction the prism cuts off half of the back lens of the objective, the resolving power is curtailed accordingly. To pay big prices for Zeiss lenses of high N.A. and then deliberately to cut down by the prism illuminator the resolving power to much less than that obtainable with a lens of similar focal length at a fraction of the cost, argues a very poor acquaintance with the theory of the instrument. Since this loss of resolution operates chiefly in one direction, there is a tendency for a circular object to be drawn out into an ellipse. Further, rows of globules oriented in the direction of the longer axis of the ellipse are much more likely than ever to be rendered as a continuous band, while laminated structures may appear structureless or be correctly resolved, according to the direction, Fig. 3. The marked superiority of the disc should need no further emphasis.

As one would expect, the strength of the source of light is shown to be without effect on the quality of the photograph produced. When vibration is considered, however, and this is rarely absent from steel works laboratories, the much shorter exposure required with powerful arc illumination, renders it then possible to obtain sharper negatives than with weaker lighting. In connection with vibration it is suggested that the objective should be separated from the body tube, which will result in a considerable decrease of mass in those parts specially sensitive to vibration, whereby the amplitude of the latter will be reduced and non-recurring.

While considering this point, the following is of importance. Given a certain primary image, this can be magnified in two ways. In the first place, it may be eye-pieced strongly, or alternatively, an eye-piece of lower magnification can be used with a long camera extension. Given absolutely rigid conditions there does not appear to be very much to choose between the two methods, although perhaps the long camera

is better since, in general, a larger field would be obtained. In cases where vibration may make its influence felt, long camera lengths rarely yield satisfactory results, since the extent of the oscillations increases with the length. It would appear, therefore, that in this case on the few occasions when it is necessary to push the magnification of a given image as far as possible, it is advisable to use a high eye-piece and short camera extension rather than the reverse.

In connection with the use of the projection eye-pieces it was discovered that the setting, *i.e.*, the relative positions of eye and field lens, which requires adjustment for different lengths of camera, is dependent not only on this and on the ocular used, but also upon the objective. The effect of the latter is shown to be considerable, and the statement made that "the possibility of movement of a projection eye-piece is practically superfluous," must be admitted to carry weight, although it is at variance with present notions. Four diagrams are given in which the camera length is related to the best setting of the eye-piece for objectives of different focal lengths.

In conclusion, another direction in which modifications of existing methods might be of value may be pointed out. Cases may well arise in which extremely oblique rays would reveal a structure in what, when viewed directly, appears to be a structureless constituent. The insertion of suitable diaphragms behind the back lens to effect this would facilitate at times the resolution of a "line" into its component dots. The general rendering of an object would be deleteriously effected by such a procedure, but in certain cases distinct advantages might be gained.

ILLUMINATION IN MICRO-METALLOGRAPHY.

By Henry M. Sayers.

In discussing this subject before this audience it is only necessary to set out certain propositions as assumed and accepted to give form and cohesion to the whole treatment. These assumed propositions are as follows:—

1. Correct illumination is essential to obtain the best results of which the objectives and oculars used are capable.

2. The principles of correct illumination are the same for the examination of opaque objects such as those studied in metallography and that of the (partially) transparent objects examined by transmitted light.

3. The illumination which permits of the utilisation of the maximum potential resolving and defining power of any objective is given by an image of the source of light projected on to the object, formed by cones of light with apex angles approximating to the angular aperture of the objective in the medium used.

4. Micro-metallography implies the use of the highest optical power available—though not necessarily in every case—and the use of photographic records.

5. Micro-metallography implies the use of some form of "vertical illuminator," and of the objective as a condenser, in all but quite low-power work.

6. It is desirable to shorten photographic exposures as much as possible, especially at high magnifications, and to avoid "glare" which reduces contrast and obscures fine detail.

7. The present effective magnification has an upper limit of about 1,000 diams., due to the limitation of the N.A. of objectives to a maximum of about 1.4 by the optical constants of the glasses and immersion media available. Any increase in N.A. and effective magnification will require a corresponding increase in illumination efficiency.

Proposition 5 sets out two conditions which constitute important differences in the application of correct illumination to opaque and to transparent objects, and give rise to the principal difficulties in attaining good illumination in metallography. The vertical illuminator entails a great loss of light. The use of the objective as the condenser also entails limitations which do not arise in the same degree when these two components of the optical system are independent.

If a total reflection prism is used as the vertical illuminator it may reflect nearly 100 per cent. of the light falling on it into the objective, but it intercepts all the light from the objective passing towards the image plane which falls on it. In the best case the prism occupies half the objective aperture, only half the objective receives light from it, and half the light going to the image is intercepted. Hence only 25 per cent. of the illuminating beam can be utilised in the image. If the prism is either larger or smaller the percentage of light getting through to the image is less than 25 per cent.

Similarly, if a cover-glass type of reflector is used the maximum illumination possible theoretically would be given if the reflector reflected 50 per cent. of the light and transmitted 50 per cent. The result would be 25 per cent. of the light utilised. No cover-glass type reflector does nearly so well as this. Measurements of a clear cover-glass have given me a reflective power of 13.8 per cent. compared with a silvered total reflection prism, and a transmission of 66 per cent., with the glass inclined at 45° to the beam. The resultant for the image illumination is therefore 13.8 × 66 per cent. or 9.2 per cent. for the image. A semi-platinised cover-glass (not made for the purpose) gave 38 per cent. reflection, but only 21.5 per cent. transmission or 8.17 per cent. for the image. The light, too, was brownish yellow.

The prism reflector, while much superior to the cover-glass in respect to illumination, cuts down the effective aperture of the objective, both as a condenser and as an objective, and does this unsymmetrically to the detriment of its resolving power. This is probably the reason why prism reflectors are never made to cover nearly so much as half the objective aperture, and they are consequently not in practice much better than cover-glasses in respect to brightness of image.

The diminution of light intensity in the image compared with that reflected by the object is proportional to the square of the lineal magnification, increased by absorption and reflection in the optical system. With 100 diameters the light intensity at the image is under one ten-thousandth, and with 1,000 diameters under one-millionth part of the light reflected by the object. Allowing for the loss due to the vertical reflector it is for the two magnifications mentioned less than one forty-thousandth and one four-millionth part respectively of the light intensity of the source for any part of the object which has perfect reflecting power, assuming that the image of the source is as bright as the source itself. As these small fractions are on assumptions of 100 per cent. efficiency for every stage of reflection and refraction between the source and the image, which is unattainable everywhere, it may be roughly estimated that the actual fractions of the source brightness in the brightest points of the image will be more nearly one ten-thousandth and one ten-millionth respectively. The most obvious improvement would be the devising of a vertical reflector giving an efficiency of combined reflection and transmission approximating to 25 per cent. without cutting down the objective aperture.

The exposure required is that for the " shadows " of the object, *i.e.*, for the darkest parts which show perceptible detail. It follows that to get reasonable exposure times only light sources of great intrinsic brilliancy are of practical use for photographic work. The total candle-power of the radiant is no criterion by itself, it is candle-power per unit area of radiating surface which counts.

Of the available sources the positive crater of the carbon arc is the most brilliant. After that come in descending order the Nernst lamp, the tungsten arc (or Pointolite), the half-watt metal filament lamp, and the oxy-hydrogen lime-light. The last named is the only light source depending on combustion at all suitable for the purpose,

but it requires cumbersome accessories and so much attention that it need hardly be considered unless an electric supply is quite out of reach.

The mercury vapour lamp ought to be mentioned, but the writer has no experience of it, can find no information as to its intrinsic brilliancy, and has seen no form of the lamp which is convenient for metallography. The nearly monochromatic quality of the light is in its favour, and it is probably capable of being put into a very useful and efficient shape for the purpose.

The arc crater gives the highest light intensity. With the requisite attention it is unsurpassable in rapidity and quality of negatives. But it has some disadvantages. The positive crater is somewhat obscured by the tip of the negative carbon, the crater surface is not always of uniform brilliancy all over, and the crater may shift during an exposure from one part of the carbon to another. Such unsteadiness may arise from the arc length being too great from an endeavour to get the negative tip out of the field of view; from impurities in the carbons, or from draughts. The arc length has to be adjusted at intervals of a few minutes. The arc does not steady down until it has been burning for several minutes. It is therefore an item of the equipment to be attended to and waited on. The arc gives off a large amount of radiant heat which has to be considered in relation to any auxiliary lens system required. It therefore leaves something to be desired in point of convenience and its rapidity in photographing is subject to some discount for the time taken in attending to it.

The Nernst lamp is excellent in many ways. It requires no globe, no attention, and is quite steady. It gives off relatively little radiant heat. It can be used on either continuous or alternating current. The shape of the radiant surface, a rod of quite small diameter is somewhat inconvenient, as it calls for very accurate centering of any auxiliary lens system. It has been unobtainable in this country for some years, as it is made only in Germany. The small diameter of the rod obliges one to magnify it considerably by the auxiliary lens system used, so that the effective brilliancy is not so great as might appear. With a one-ampere Nernst lamp I have done a good deal of work on steel at 700 to 1,000 diameters, and find the exposure required to be from five to ten minutes at such powers, using fast plates and a light filter.

The Pointolite or tungsten arc is free from the inconveniences of the carbon arc. The source of the light is a small ball of tungsten which appears in the field of view as a disc of uniform brilliancy fixed in position. Its intrinsic brilliancy from some rough tests of my own seems to be about one-third that of the carbon arc crater. It lights up at once, is normal in a few seconds, requires no adjustment or attention, and gives off a relatively small amount of radiant heat. It is very promising and the larger sizes which are being developed may prove to be as quick in work as the carbon arc, when the absence of attention and unsteadiness are taken into account. Like the carbon arc, it requires continuous current for its operation.

Half-watt lamps with straight filaments as made for motor-car head lights are quite useful. Their intrinsic brilliancy is little inferior to that of the tungsten arc. The small diameter of the coiled filament is open to the same objection as the Nernst filament, *i.e.*, it has to be

much magnified to fill the field of view, so that the effective brilliancy is reduced. Moreover the separate turns of the spiral become visible in a critical image. These small lamps can be run from a few ignition cells, so that they are convenient for portable use. Run from an ordinary supply circuit they require either a resistance or a transformer to reduce the pressure to 6 or 8 volts. Good work has been done at high powers on steel with a 6-volt 4-ampere half-watt lamp, but the exposure is two to three times as great as with a Nernst lamp. Up to 150 diameters this exposure is reckoned in seconds, so the difference is not important, but for high powers the exposure goes up to several minutes (15 to 20), it counts where much work has to be done. Long exposures are objectionable not only because they limit the speed of work, but also because they increase the risk of disturbance of the image by vibration.

The illuminations needed to give short exposures are far too bright for comfort in visual examination. The interposition of a piece of fine-grained ground glass is a simple remedy. It can be put anywhere between the light source and the vertical reflector and no adjustment is disturbed. The final focussing must be done on the ground glass of the camera, where the full illumination will not be found excessive for the purpose.

Anyone starting on micro-metallography will find his initiation much easier if he tries first visual and photographic work by transmitted light on transparent objects. As the sub-stage condenser is independent of the objective it is much easier to try variations of focus and illumination, and the knowledge so gained helps very much to recognise proper and improper condition in opaque work. Good objects for such training are section of Echinus spine for low powers, and diatoms of various fineness of structure for the higher ones. A student who can get a good dark round negative of Echinus spine at 100 diameters, and good " black-dot " negatives of Pleurosigma Angulatum or Surirella Gemma at 1,000 diameters with an oil immersion objective will find work on metals much simpler than if he came to it without such practice. The superior resolving power and definition of a given objective with the sharp image of the illuminant focussed on the object from a sub-stage condenser of aperture comparable to that of the objective will be appreciated.

In metallography (excepting with the very low powers) the objective plays the part of the sub-stage condenser as well as its own. To obtain a sharp image of the source of light upon the object when the object is focussed to the eye-piece, certain distance relations between the illuminant, the objective, the object, and the image plane must be observed. They are simple. The light source must be at the same distance from the back lens of the objective as the image plane, the distances being measured along the path of the light in each case. Obviously the source and its image on the object are at the conjugate focii of the objective; and the object and its image are at equal conjugate focii. An immediate consequence of this relation is that the illuminated field or useful part of the image formed by the objective is of the same dimensions as the source (real or virtual) of light itself. If, for example, the source of light is the crater of an arc, one-tenth of an inch in diameter, the usefully illuminated part of the real image

formed by the objective will also be one-tenth of an inch in diameter. This identity of dimensions is independent of the power of the objective. A two-third inch with a power of 8 and a one-twelfth inch with a power of 100 with both give an illuminated circle of one-tenth inch diameter in the image plane, provided that the conditions of critical illumination are observed. If the total magnification on the camera screen is ten times the objective image magnification, the effective field will be one inch in diameter. This is generally too small for practical use, and is much smaller than the field which the objective can cover. One wants a field at least three inches in diameter to cover a quarter plate. The assumed magnification of ten due to the ocular and camera length combined is about as much as the best objectives will usefully stand. So that to cover a quarter plate the radiant should be from a third to a half inch in diameter.

Unfortunately the avallable sources of light are of small area. An arc crater of a quarter-of-an-inch diameter corresponds to an arc current of 30 to 40 amperes, and is not really large enough. As the crater diameter increases only as the square root of the current, one would require a searchlight arc, with many tens of amperes to give a crater three-quarters of an inch in diameter, which is about the ideal size to fill an eye-piece. Such an arc is not practicable. Even a 40 ampere arc gives out too much radiant heat to be brought within the few inches of the microscope corresponding to the posterior focus of the objective. The same difficulty of small area is true of the other available sources. The 100 candle-power Pointolite has a radiant surface about one-tenth of an inch diameter. The Nernst and half-watt lamps have filaments of much smaller diameter. There seems no good reason why a half-watt spiral lamp filament should not be made one-third or one half-inch diameter. There may be manufacturing difficulties, or it may be that the makers have not seen that there is any use for such lamps. If made the spiral, or rather helix should be flattened to bring the radiant surface as nearly as possible into a plane.

The actual radiant surface therefore has to be magnified in some way to give a field of sufficient area. The simplest way is to use a short focus condenser to project near the upper lens of the objective an image of the radiant. This can be focussed on to the stop of the vertical illuminator, and the fine focussing done by eye. The image thrown on the object is that of the aperture of the condensing lens which is then at the posterior focus of the objective. A condenser of the Nelson type of two inches full diameter, stopped down to one inch aperture works well. It must be carefully centered to the radiant, and both must lie on a line at right angles to the optical axis of the microscope. To make these adjustments readily, some form of mounting equivalent to an optical bench, with vertical and horizontal movements to either the lamp or the lens is necessary. If the lens is always used for the same stand, it can be fixed at the height of the optical axis, and the adjustments for centering made on the lamp carrier. Movement to and from the microscope to adjust the lens distance to the optical tube length in use—which may be different with different combinations of objectives and oculars—and some movement parallel to the body to allow for the range of movement of the illuminator aperture, are necessary. These statements hold true for any of the auxiliary arrangements described.

The condenser must be of short focus in order to take in a large cone of light from the radiant. The Nelson condenser mentioned has a working distance of about one-and-a-half inches. This is too short for an arc of even ten amperes, but with a Nernst or half-watt lamp up to 100 candle power the heat will not injure it. The Pointolite lamp of 100 candle power has a bulb which is just too large for such a condenser to focus at the required distance.

Another arrangement is to set up a screen with an aperture of the required size, say seven-eighths inch to one inch, which may conveniently be an iris, at the required distance and to throw on that aperture a magnified image of the radiant. The image formed by the objective on the object will then be a reduced one of the radiant. This arrangement takes up a good deal of room. Thus if the aperture is one inch in diameter and the radiant quarter-inch diameter, and a lens of four inches focal length is used, the total distance from the microscope body will be from 32 to 36 inches, which is awkward for making the adjustments, attention to the arc, etc. It is doubtful whether a lens of four inches focal length could be safely used with an arc giving a quarter-inch diameter crater. A six-inch or eight-inch focus would probably be required and proportionately more distance occupied. It follows that there is not really much advantage in using radiants larger than those which permit of the use of lenses of about two inches focus. More light is produced, but no more is utilised.

A third method is to present to the objective a virtual image of the radiant, *i.e.*, to use an auxiliary lens as a simple magnifier, the objective taking the place of the eye. The focal length difficulty comes in again, as the lens must be closer to the radiant than its focal length. A lens combination with its equivalent plane well in front of it, so that the working distance from the radiant is greater than the focal length, gets over this. Such a combination which I have used with success is a Nelson condenser with a flint concave between it and the microscope. The combination is really a microscope of the Brucke type. The concave is placed close up to the aperture of the vertical illuminator, and focussed by moving the radiant to or from it. As the radiant and condensing combination are both within a few inches of the microscope body, adjustments are easily made while observing the object. The image given by the objective is a real image of the radiant. The magnification may easily be ten times.

Whatever arrangement is used there should be provision for interposing a ground glass or light filter in the path of the beam. For metallography a light filter is not needed for securing contrast as in stained specimens photographed by transmitted light, but for cutting out the chromatic residuals given by even the best objectives. The sharpest visual focussing on the camera screen without a filter fails to give an equally sharp negative. A green filter, such as the F line filter, or a malachite green gives sharper results without a great increase in exposure.

With either of the two first named auxiliary arrangements a glass micrometer can be placed in the focal plane which is the virtual radiant and the scale image focussed on the specimen can be photographed at the same time. This is equivalent to an eye-piece micrometer. Its size on the camera screen is a measure of the magnification

due to the ocular and camera length. Like any eye-piece micrometer, its actual value needs to be calibrated against a stage micrometer, but it is available with any eye-piece.

There remains the difficulty of "glare." The worst source of this trouble is reflection from the surfaces of the objective lenses. The upper convex surfaces are the strongest reflectors. Fortunately the condition that the illuminating beam should fall as if it proceeded from the image plane, means that it is made up of divergent rays which a convex reflector cannot bring to a focus, but reflects with an increased divergence. Consequently with the light focussed correctly only a small spot of glare light appears at the apex of the upper objective lens. The bulk of the reflected light is scattered to the tube sides. Obviously the objective mount and body tube should be well blacked inside. Reflections from the inside of lamp bulbs and other stray light may give trouble. It is best to keep all these away by a screen, which may be the mount of the auxiliary lens or aperture. Another source of glare is reflection from the front lens of the objective. It is only troublesome with dry objectives of short working distance. With those of 2/3 inch and over it is not serious, but it is hardly possible to get negatives with good contrast with dry objectives of 1/4 or 1/6 inch. Perhaps this is one reason for the fact that very little metal work is done at magnifications between 150 diameters, the upper limit of a 2/3 inch or 16 mm. objective, and 700 diameters corresponding to a 1/12 inch or 2 mm. oil immersion. One can, of course, get intermediate magnifications by using low ocular and camera length with an oil immersion, but the field covered is too small for the general view required. The Zeiss 3½ mm. or 1/7 inch oil immersion fills the gap very well. I have tried to get English firms to make a similar lens, and one maker listed a 1/6 inch oil immersion for metallurgical purposes before the war, but has ceased to make it. I would suggest that a 6 mm. or 8 mm. oil immersion should be made for the work. The working distance need not be too great for the oil contact, no cover glass has to be allowed for, conditions favourable to giving the objective a relatively large N.A. without introducing specially great manufacturing difficulties. The Zeiss lens mentioned was quite cheap, and of excellent performance. A one inch or 2/3 inch of about .30 N.A., a 1/3 or 1/4 inch oil immersion of about .70 N.A., and a 1/12 inch of 1.3 to 1.4 N.A. would furnish a metallographer with a battery serving all the purposes.

For low power work there is room to put the vertical illuminator below the objective, and it can be arranged to give either vertical or oblique light. Even here it will be found advantageous to use an image of the radiant formed by an auxiliary lens.

To sum up the above, it may be said that the items in which improvement is desirable are the following:—

1. A transparent vertical illuminator which shall get nearer the theoretical perfection of reflecting 50 per cent. and transmitting 50 per cent. of the light incident on it at 45°, without colouring the transmitted light. Optically worked glass lightly platinised seems the most promising.

2. A light source of uniform and steady high brilliancy presenting an area of half-an-inch square or a little more, to which a condenser of 2 inch working distance can be focussed without damage from

radiant heat. Either the half-watt or the Pointolite lamp may be able to meet this. The limitation of bulb size is important.

3. Oil immersion objectives intermediate in focal length and aperture between the 2/3 inch and the 1/12 inch, well corrected for colour. If anything can be done to reduce glare from internal reflection in the objectives designed for metallography it will be an advantage.

4. An auxiliary condenser combination with a long working distance compared with its focal length to be used to present a magnified virtual image of the radiant to the objective. Suitable specification would be:—

Focal length, $1\frac{1}{2}$ inches to 2 inches.
Working distance—anterior—3 inches to 4 inches.
Clear aperture, $\frac{3}{4}$ inch to 1 inch.
Well corrected spherically and chromatically.
Mounted with a flange or a flanged collar.
Cost reasonable.

5. A simple firm optical bench or geometric slide arrangement with carriers for lamp and condenser at heights corresponding to those of usual microscopic axes when in the horizontal and vertical positions. The whole bench or slide to be capable of movement parallel to the microscope axis for 2 or 3 inches.

THE USE AND NEED OF THE MICROSCOPE IN ENGINEERING WORKS.

By S. Whyte, B.Sc.

It is not necessary in these days to set out in detail the practical help which is derived from the use of the microscope in engineering. Everyone knows the great benefit it has been in controlling the question of steel supplies and their heat treatment. By its means inherent defects in the steel are discovered. Troubles may arise at the steel works through bad ingot pouring, and any pipes or seams which occur in the portion of the ingot which is used finds its way into the billets and bars. Also, faults may arise in the forging or stamping of the steel which are difficult to detect without a microscope. For finished parts the microscope is almost essential in working out and standardising the best methods of heat-treatment, and in the event of failures of these parts in service, in helping to discover the processes by which these failures originate and develop. This by no means exhausts the list of uses to which the microscope can be applied in examination of metals for engineering works, as the properties of castings—both ferrous and non-ferrous—can be co-related with their various micro-constituents and their distribution or crystalline arrangement.

The writer does not propose dealing in detail with the various branches in which, from his own experience, he has found the microscope to be of great value. It is sufficient to say in passing that the microscope ought to be, and will be in the near future, an essential part of the average engineering works equipment, especially where the products being manufactured are subjected to live loads, and on which the safety of life depends.

The purposes for which the microscope is used, as outlined above, are three-fold, and endless examples could be given.

First, in the examination of raw material, as supplied by the steel makers and stampers. It is not enough in all cases to buy merely to chemical specifications, as two pieces giving the same analysis may differ in their usefulness. One may be sound, while the other shows segregations and results of ingot piping. Faults such as these, however, are becoming rare, as the improvements in recent years, specially in regard to ingot casting, have done much to eliminate them. It is, however, still important that samples of new types of stampings, as they come from the makers, should be examined for incipient cracks or "laps" of oxide driven into the material, specially when the stampings are intricate, and the steels used are alloy steels. It is impossible to tell, other than by the microscope, that some of these flaws exist, and it will help the stamper to correct his dies, and will save time and expense and the possibility of subsequent failures from this cause, if defects can be detected from the beginning. Micro. No. I. is an example of this type of defect.

Secondly, and what is more important from the engineer's point of view, the microscope is a great help in arriving at the best heat-treatment temperatures for his steel. It is absurd to buy expensive high-grade alloy steels, and not use every means of obtaining the best results from them. It is equally extravagant to buy high-speed steel for tools

and waste it, and much time in the machine shop, through bad hardening. For machine parts, pyrometers and testing machines are necessary in standardising methods after the temperatures have been established, but with high-speed steel, where the hardening temperatures are usually high, the recording of these temperatures is not so reliable and calls for all the more precaution in testing the conditions by micro-examination of the steel after hardening. Micros. Nos. II. and III. show the structure of an 18 per cent. tungsten steel heated to a satisfactory temperature, and overheated, respectively. The overheated, or burnt structure of No. III., shows the large crystals of austenite with oxide beginning to form round their boundaries. On the other hand, the best cutting properties of the steel are not brought out unless the steel is heated to a temperature high enough to diffuse all the free iron tungstide, which is present in the annealed condition. Micro. No. IV. shows the same high speed steel where the hardening temperature has not been high enough or the time of soaking not long enough, and too much free tungstide is still present.

Thirdly, and most important for the engineer, is the use of the microscope in helping to locate the causes of failures, and in working out the processes by which these fractures develop. The causes of failure are numerous, and apart from those due to inherent defects in the steel as mentioned above, the principal one is that of " fatigue." In " fatigue " fractures, the origin is usually found in a weakness of design or in using steel of too low an elastic limit. Sometimes a piece of non-elastic slag, occuring at a point of maximum stress, sets up local stresses high enough to start a fracture. In designing machines, a radius replaces a sharp corner whenever possible, when working stresses are set up at these points, so that the stresses shall be distributed as evenly as possible. Sometimes one finds an accidental notch, such as a file mark. in a radius, which sets up a " fatigue " fracture. An example of this may be given, as it brings out points in connection with the microscope objectives, which appear to be worthy of consideration. Micro. No. V. shows such a V-notch, accidentally made by a file in the radius at the foot of a stop in a machine gun lock mechanism, which received rapidly repeated blows. The notch has concentrated the stresses to such an extent that overstraining of the material has taken place, and a crack is seen originating at the apex of the notch. The crack, as it develops, is seen to be deflected through a slag inclusion, Micro. No. VI., and in other places in the same specimen it was noticed that " strain picture " was highly developed round these slag inclusions, although fracture had not commenced.

In microphotograph No. VII. this strain structure is also seen around the end of the crack which had penetrated about 1-16 in.

It is in cases such as the above that good objectives are necessary, and more so when alloy steels are being examined. In non-ferrous metals the crystal grains are usually much larger, and strain structure is easily resolved with comparatively low magnifications. Microphotograph No. VIII. shows a brass which had been strained during machining.

It is in photographing the fine-grained steels that the differences in the microscope objectives show up. In photographing Micro. No. VII. the secondary spectrum of the achromats would give bad definition but, with the elimination of this in the apochromats, by the union

of three colours of the spectrum at one point instead of two in the achromats, a great improvement is effected. This, with the correction for spherical aberration in two colours, gives an image of greater sharpness for either white or monochromatic light.

For low power work, however, and for certain subjects on higher power work, a flatter field and better results can often be obtained by achromatic objectives, as the larger aperture of the apochromats tends to give a slight curvature of the image, which even the compensating or projection ocular cannot entirely correct.

At the same time it is felt that even the best made German objectives do not give enough magnification for micro-photography, as the very fine structure of some alloy steels are at present most difficult to resolve, and much that is now impossible to see might be brought out under higher magnifications. Microphotographs Nos. IX. and X. show " etch figures " in crystals of pure nickel. These serve to determine the crystalline system to which nickel belongs. The crystal in Photograph No. IX. shows a twinning plane, and the consequent difference of orientation as shown by the " etching pits." It is impossible to say what internal structures might be brought out in heat-treated alloy steels by higher magnifications, as the crystal grains are so much smaller than those of the nickel shown in Photographs IX. and X.

For metallographic work the following provisions on the microscope seem, to the writer, to be advisable for good work. The microscope should be usable in the horizontal position.

The stage should have a mechanical movement in two directions, at right angles to each other. The stage should also have a racking motion for focussing, as it is usually more suitable to rough focus by this means in preference to that on the tube, as it does away with the necessity of altering the position of the optical bench. The fine adjustment is usually on the tube of the microscope, and this is the most convenient place.

Ordinary Huygenian eye-pieces are most suitable for achromatic objectives, while for the apochromatic objectives special compensating eye-pieces are necessary. For photography a projection eye-piece gives the best results.

The disc illuminator gives most satisfactory results and, with a diaphragm between it and the source of light, good definition can be obtained.

The objectives as mentioned previously should be used according to the subject—the achromats give every satisfaction for the general run of metallurgical work and, even in photography, are often preferable to the apochromats, by giving a flatter field. However, when photographic records of very fine detail are desired there is no doubt of the superiority of the apochromats for the purpose.

It seems to be desirable to be able to obtain much higher magnifications than are at present obtainable by the present objectives, but, in all probability, improvements in the methods of polishing the specimens will also have to be developed to secure a surface good enough to bear the higher magnification.

There is undoubtedly a great future before the microscope in its application to engineering work, in relation to designs, steel and its heat-treatment.

FIG. 1.

Spec.: Small Forging.
Illum.: Vertical.
Camera: 66 cms. Obj.: 20 mm.
Ocu.: Projn. Mag.: 90 diams.
Etched: Picric Acid.
Remarks: Slag driven into steel along with some decarbonised layers from the surface. .42% C. steel.

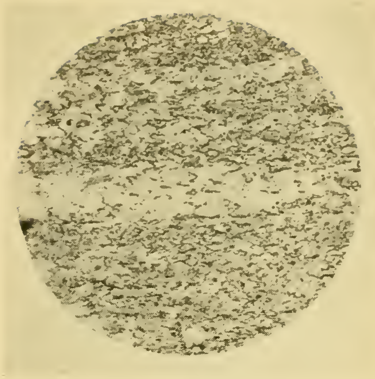


FIG. 2.

Spec.: High-speed Steel.
Illum.: Vertical.
Camera: 78 cms. Obj.: 4 mm.
Ocu.: Projn. Mag.: 500 diams.
Etched: Picric Acid.

Remarks: Fine Grains of Austenite with traces of free tungstede steel unabsorbed. (White globules.)

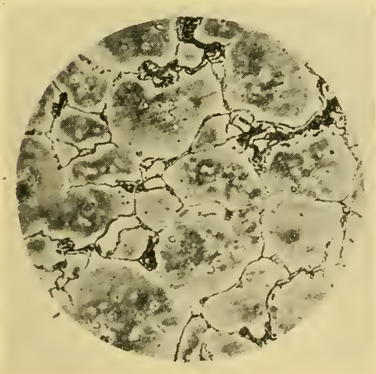


FIG. 3.

Spec.: High-speed Steel.
Illum.: Vertical.
Camera: 66 cms. Obj.: 2 mm.
Ocu.: Projn. Mag.: 1,000 diams.
Etched: Picric Acid.

Remarks: Large grains of Austenite surrounded by oxide.

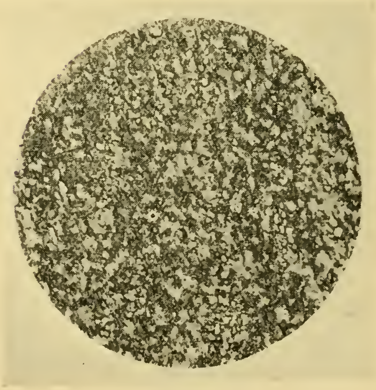


FIG. 4.

Spec.: High-speed Steel.
Illum.: Vertical.
Camera: 78 cms. Obj.: 4 mm.
Ocu.: Projn. Mag.: 500 diams.
Etched: Picric Acid.
Remarks: Fine grains of Austenite with considerable amount of free tungstede. (White globules.)

FIG. 5.

Spec.: Machine Gun Mechanism.
Illum.: Vertical.
Camera: 78 cms. Obj.: 4 mm.
Ocu.: Projn. Mag.: 500 diams.
Unetched.
Remarks; File mark in radius at bottom of extractor stop.

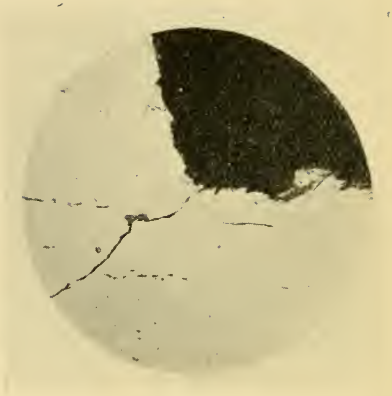


FIG. 6.

Spec.: Machine Gun Mechanism.
Illum.: Vertical.
Camera.: 61 cms. Obj.: 2 mm.
Ocu.: Projn. Mag.: 1,000 diams.
Unetched.
Remarks: File mark in radius deflected alongside slag patch.

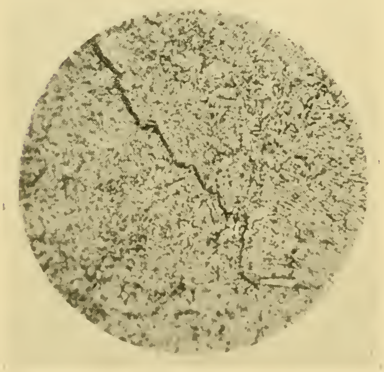


FIG. 7.

Spec.: Machine Gun Mechanism.
Illum.: Vertical.
Camera: 92.5 cms. Obj.: 2 mm.
Ocu.: Projn. Mag.: 1,500 diams.
Etched: Picric Acid.
Remarks: Strain in structure round crack in .50% C. steel. Troostitic condition.

FIG. 8.

Spec.: B. Brass.
Illum.: Vertical.
Camera: 55 cms. Obj.: 4 mm.
Ocu.: Projn. Mag.: 250 diams.
Etched: Ammonium hydrate.
Remarks: Shows junction of three crystal grains. Each with own system of slip bands.

FIG. 9.

Spec.: Nickel Rolled Bar.
Illum.: Vertical.
Camera: 92.5 cms. Obj.: 2 mm.
Ocu.: Projn. Mag.: 1,500 diams.
Etched: Nitric Acid.
Remarks: Etching pits in nickel crystals.

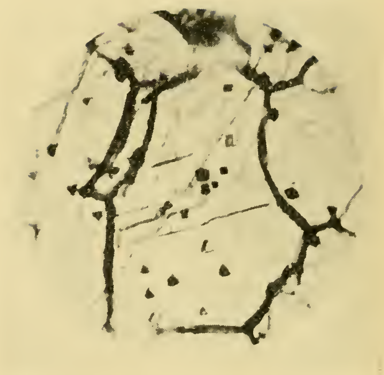


FIG. 10.

Spec.: Nickel Rolled Bar.
Illum.: Vertical.
Camera: 92.5 cms. Obj.: 2 mm.
Ocu.: Projn. Mag.: 1,500 diams.
Etched: Nitric Acid.
Remarks: Twinning plane in nickel crystal with resulting difference in orientation.

SUGGESTED IMPROVEMENTS IN THE METALLURGICAL MICROSCOPE

By Professor H. Le Chatelier (*Paris*).

The writer has for some considerable time been endeavouring to extend the use of the Microscope in Metallurgical Works. No one to-day will contest the services that Metallography renders to Industry, and it is possible that the sphere of usefulness of this method of investigation could be still further extended by improvements in detail.

The object of this brief note is to point out two possible improvements.

In the first case, to obtain good photomicrographs the use of apochromatic objectives is necessary. These are very costly and many workers hesitate to incur the expense of providing them. Would it not be possible to persuade Manufacturers to design Objectives corrected for some single wave-length of the spectrum ?—viz., the blue line of the Mercury Vapour Lamp, which is easily separated from the other rays and which moreover has a considerable actinic effect. Such simple objectives in which it would only be necessary to take into account corrections for spherical aberration could be manufactured as a single lens and would thus be comparatively cheap.

The second improvement, which it is desirable to introduce into an objective used for the examination of metals is to give to the radius of curvature of the back surface such a value as to prevent concentration of the light reflected from this surface. In all Metallurgical Microscopes illumination must necessarily be effected through the objective. This is a new condition and consequently one complication more in the construction of objectives, but perhaps it may not be insuperable.

From an entirely opposite point of view it would be very useful if a small handbook were drawn up for the use of those who employ the Microscope, as well as for a few of the Manufacturers, such a manual explaining the essential properties of the instrument. Every day the grossest errors are made in this connection. A great number of experimenters imagine that a Microscope Objective can be used like a thin lens. They forget that every objective is constructed to give an image at a fixed point, this being 16 or 25 centimetres according to the country of manufacture. We frequently see photographs taken with a Microscope objective, in which the adjustment (tube length) is changed so as to project the image a greater or lesser distance according to the magnification it is desired to obtain. Now, on the contrary, the extension of the Microscope should always remain invariable and a projection eye-piece used for taking the photomicrograph. The distance of the two lenses of this eye-piece should be adjusted according to the magnification desired.

Another practice which should be no less condemned when using the Metallurgical Microscope is that of reflecting the luminous pencil at right angles by means of a total reflection prism placed in the path of the pencil of light, instead of employing a silvered reflecting mirror. The former method completely changes the working of an objective by making the pencil of rays pass through a piece of glass many centimetres thick. The objective is calculated for working in air and not in glass.

These errors are not very important when the examination is simply by the naked eye, because the eye has an extraordinarily high degree of accommodation. This, however, is not the case in photography. Frequently the sharpness of image that ought to be possible where objectives are properly used is far from being obtained.

To sum up: hitherto Microscopes have only been seriously investigated for the examination of transparent objects and it would be highly desirable if this study could be resumed and extended with a view to the examination, by reflection, of polished opaque bodies like metals.

SUGGESTED ALTERATIONS IN THE DESIGN OF THE LE CHATELIER TYPE OF METALLURGICAL MICROSCOPE,

By Professor F. Giolitti (*Italy*).

It is well known that the principles laid down by Le Chatelier for the design of his instrument have been applied, with different constructional details, by various Makers and it is also recognised that the design of the Le Chatelier Microscope which has found greatest favour is that adopted by Pellin of Paris and Dujardin of Düsseldorf.

I have had long and practical experience of this latter type of design, and I do not think I am wrong in stating that, even though the Le Chatelier Microscope offers the best solution of problems connected with the microscopic examination of metals, and is much preferable to all similar types of apparatus on the market, it has two disadvantages, which, however, are quite easy to rectify by means of some simple modifications in constructional detail.

The first of these disadvantages consists in the fact that the rack which supports the stage is directly fixed " on one side " of the stage, so that the weight of the stage and of the object placed upon it tends to produce a sagging of the rack.

This sagging effect becomes more and more pronounced as time goes on, and prevents the focussing of the whole of the metallic section under examination. It is intensified, and in a short time may seriously damage the instrument when it is required to examine fairly heavy specimens, and this is a case which frequently occurs in practice.

The second disadvantage consists in the absence of an apparatus, which, like the revolving objective holder in the ordinary Microscope, permits of rapidly and easily changing the objective. In the Le Chatelier instrument, in order to change the objective, it is necessary to raise the stage, unscrew the first objective, screw the second objective into the place of the first, lower the stage, and refocus. This operation is very long and tedious, and it is even more so when, with a view to preventing the inconvenience of allowing the various objectives to remain uncovered on the work table, it is necessary each time to put back into its case the objective which has been removed from the Microscope and take out of its box and fix on the instrument the new one required. And, of course, it is often necessary to examine each metallic section under various magnifications, in order to find out with accuracy the true significance of the various structural elements, and eliminate errors in the interpretation of the structure.

For these reasons I have studied, with the help of Dr. A. Filippini of Genoa (to whom I extend my heartiest thanks for his valuable collaboration), a type of Microscope which, while still preserving the extremely useful fundamental principle of the " vertical " observation which makes the Le Chatelier Microscope so practical, gets over the disadvantages to which I have referred.

The new Instrument differs from similar apparatus principally by the addition and different arrangement of a few of the external parts, which are clearly shown in the illustration, Fig. 1.

I will, therefore, only refer very briefly to the features of these parts, without touching upon anything regarding the other components of the Microscope—such as method of illumination, system of projection, etc.—which do not differ essentially (except for the special

design rendered necessary owing to the new type of construction) from the corresponding parts of other similar apparatus.

As is clearly shown in the illustration, in the new instrument I have endeavoured to eliminate the first of the two disadvantages mentioned, by supporting the stage by a bar fixed to it at two opposite points. The bar is, in its turn, supported by the rack, the axis of which coincides with the perpendicular of the stage, carried through the centre of the stage itself. It is evident that in this way the defects due to the sagging of the rack are eliminated, provided care is taken in centreing the objects to be examined in the middle of the stage.

In the instrument constructed by Messrs. Reichert it is possible to support on the stage specimens weighing several kilogrammes, without any appreciable deviation from the normal between the optical axis and the plane of the polished surface resting on the stage.

Owing to the frequency of cases in which in practice it is necessary to place very heavy objects on to the stage, I have thought it necessary to take the weight of the object off the fine focussing micrometer screw, by fixing—as will be seen in the photograph—the screw itself to the slide which carries the tubes of the visual and projecting eyepieces. The result is that the coarse movements and approximate focussing are effected by moving the stage, while the comparatively delicate movements required for very fine focussing are made by manipulating the eyepiece tubes. It will be recognised, owing to the smallness of the movements necessary to bring the objects into correct focus, that such a modification does not detract from the proper illumination of the object.

I have overcome the second disadvantage mentioned by adding to the microscope a proper revolving holder for 4 objectives. The use of the revolving holder offers some difficulties in this case; both owing to the necessity for fitting it in such a way as not to hamper the various functions of other components of the instrument, and with a view to preventing any modification in the characteristic dimensions of the objectives by deviating from those which give the best results in the examination of opaque metallic specimens illuminated by reflected light. The first difficulty has been overcome by replacing obliquely the bar which supports the stage, in the manner shown in the photograph. The second difficulty has been eliminated by giving to the revolving objective holder the special shape represented in the same illustration.

The above description refers to the design of instrument for visual observation. The complete apparatus as used for Photomicrography is shown in Fig. 2.

In addition to the advantages mentioned above, the new Microscope offers still another—not indispensable—of permitting the oblique illumination of the specimen examined with the low power objectives. The adjustment for oblique lighting, which already existed in the Metallurgical Microscope designed by Martin, had to be abandoned, from considerations of manufacture, in that of Le Chatelier, but it has been satisfactorily applied in the new instrument, thanks to the special design of its essential parts.

For the reasons already referred to, it is unnecessary for me to describe the new instrument in more detail. I would only add that in practical application the features of design which I have briefly outlined above have shown themselves to be extremely useful.

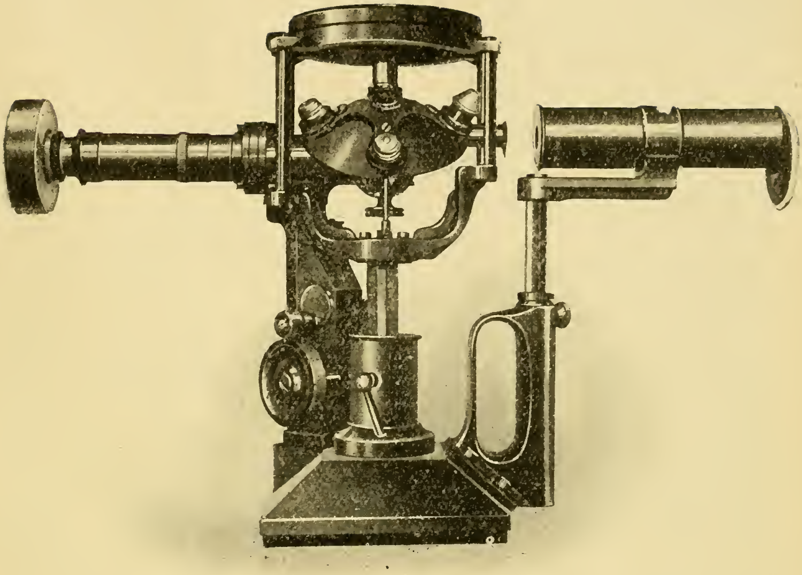


FIG. 1.

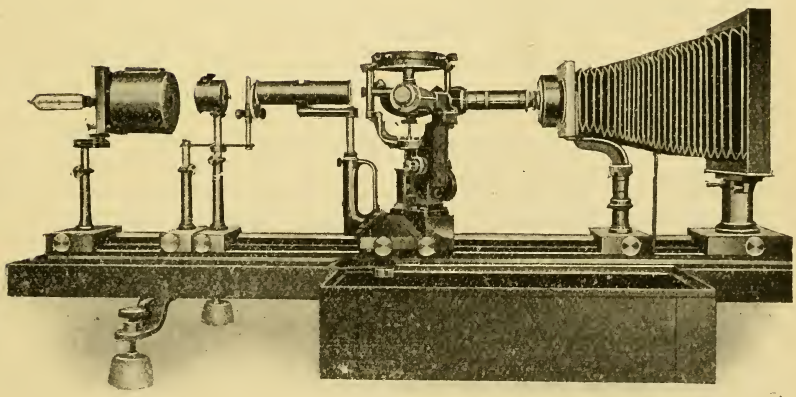


FIG. 2.

IMPROVEMENTS IN METALLURGICAL MICROSCOPES.

By Albert Sauveur (Harvard University).

At the kind request of Sir Robert Hadfield, I am submitting this slight contribution to the symposium on the microscope and its applications. Referring first to the minor improvements I have been able to introduce into the construction of metallurgical microscopes, I venture to mention the following points.

It is, I believe, at my suggestion that microscopes for metallurgical work were first constructed by the Bausch and Lomb Optical Company, of Rochester, New York, with a stage that could be racked up and down in a manner similar to the substage attachment, thus affording greater working distance, and doing away with the necessity of ever having to displace the vertical illuminator, the condensing train and the source of light as objectives of varying focal lengths are used. It is also at my suggestion that in inverted microscopes and in the vertical-horizontal type herewith illustrated a totally reflecting prism was attached to a horizontal draw tube, affording a ready means of pushing it in or drawing out of position as desired.

The two types of metallurgical microscopes used almost exclusively in the United States are shown in Figs. 1 and 2, special attention being called to what may be called the horizontal-vertical type (Fig. 1), in which a vertical microscope is used for visual work, while a permanently connected horizontal camera is used for photographic work. It is believed that this arrangement presents some decided advantages over the vertical type as well as over the inverted type. I do not believe that these instruments have ever been surpassed by those of German manufacture.

The magnetic holder which I designed many years ago for holding iron and steel specimens has proved, I believe, very serviceable, and is widely used in the United States.

As to the directions in which metallographic investigation should be stimulated as more likely to bring valuable results, I am not one of those who believe that much is to be expected from examination at greatly increased magnifications. Confining my remarks to iron and steel, with the exception of the occurrence of carbon, we are still greatly handicapped by the lack of methods by which other constituents and impurities can be identified and their occurrence studied, and it seems to me that we should endeavour to remedy this condition. Let us briefly consider the various elements or chemical compounds present in industrial iron-carbon alloys.

Carbon.—We have at our command satisfactory means of distinguishing under the microscope the various forms in which carbon occurs in these alloys. I am not of the opinion that carbon may be present, as some believe, in a much greater number of varieties than we are now able to identify, and I do not believe that examination under greatly increased magnification or other methods would advance much further our knowledge of the behaviour of that vital

element. Carbon is present in iron-carbon alloys either as graphite, or as the carbide Fe_3C, which may be free or which may form with iron a solid solution. I am not attempting at present to distinguish between solid solutions and colloidal solutions or emulsions. I believe that the hardening of steel is due to the retention of the carbide Fe_3C in a solid solution, but I also believe that the solution thus retained by rapid cooling is allotropically different from the solid solution stable above the thermal critical stage.

Phosphorus.—It is believed on good grounds that phosphorus exists as Fe_3P in iron, but unless there is a considerable percentage of carbon present one cannot under the microscope detect the presence of that compound, owing to the fact that it forms with ferrite a solid solution. A method by which steel high in phosphorus could be differentiated under the microscope from one low in phosphorus would be of great service. To be sure, it is believed that segregation of phosphorus may be detected by the Stead's reagent or by similar reagents, but in the light of recent research we are in doubt whether the segregation which we have been in the habit of attributing to the occurrence of phosphorus may not be due in some cases to the presence of some other element or elements; for instance, to the presence of oxygen. Obviously better means of identification are needed.

Sulphur.—We have satisfactory ground for our belief that sulphur in steel unites with some of the manganese present to form particles of manganese sulphide distributed somewhat irregularly in the metal, and that it may also form a sulphide of iron. These can be detected quite readily under the microscope. It is not certain, however, that the dove-coloured inclusions generally assumed to be manganese sulphide contain no other constituents, nor do we know positively that sulphur forms no other compound and that it is not present in any of the other constituents detectable under the microscope.

Manganese.—We believe that some of the manganese present in steel forms, as stated above, manganese sulphide, as well as manganese carbide, and also that some of it is present in solild solution in iron, but with the exception of manganese sulphide it is not possible to detect the presence of manganese in any of its other forms under the microscope.

Silicon.—Silicon is generally supposed to be present as an iron silicide dissolved in iron. It is not possible, however, to verify by the microscope the accuracy of this belief.

Special Elements.—Microscopical evidences of the form in which special elements, such as nickel, chromium, tungsten, vanadium, etc., occur in steel are lacking.

I believe that the discovery of etching or other methods that would permit a more thorough and more exact microscopical analysis of iron and steel and of their inclusions would be of great assistance in the further development of metallography.

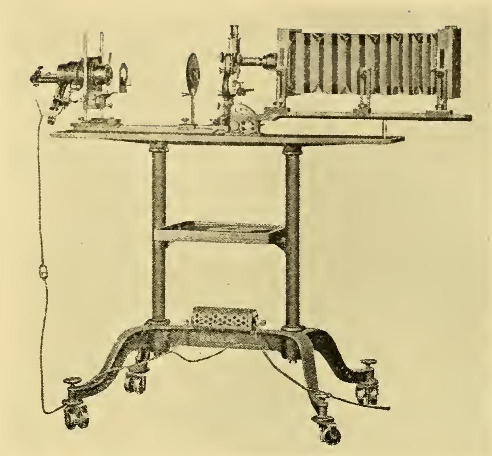


FIG. 1.

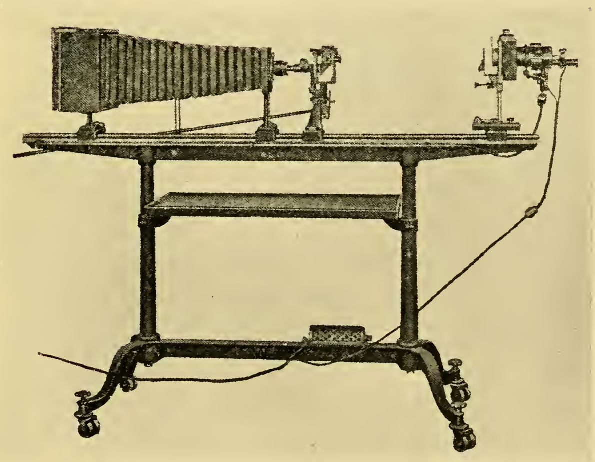


FIG. 2.

SOME POINTS CONCERNING SHARPNESS IN HIGH MAGNIFICATION MICROGRAPHS.

By Carl Benedicks and Erik Walldow (University of Stockholm)

1. *Microscope and accessories used.*

The following will give a short account of some optical studies executed by us, using the new-constructed metallographical microscope of C. Reichert of Vienna.

The most prominent feature of the new microscope, which is constructed according to the Le Chatelier type, is the very convenient interchangeability of the plain glass illuminator and the prism illuminator. This interchangeability was introduced in consequence of a short paper by one of us,* in which evidence was given of the superiority of the former illuminator at high magnifications. Another innovation is the very convenient adjustment, with index and scale, of the position of the prism—which is of the Le Chatelier type, with two reflecting surfaces—so as to enter more or less, according to the focal length of the objective.

Another detail of the construction is, that the coarse adjustment is operated by a rack and pinion motion of the stage on which the specimen rests (face downwards), whilst the fine focussing is obtained by a micrometer slide motion of the objective and tubes. The advantage is, that a heavy weight on the stage will have no influence on the delicate slide motion.

For photographic work, a green glass filter was used, giving a rather well-defined wave length of 0.5-0.6 μ. Orthochromatic plates (Wellington, anti-screen, backed) were used, and an arc lamp of about 350 c.p., the duration of exposure was increased by this filter in the ratio 10:1. The regular exposure (with filter) was 20 secs. when the glass slide illuminator, 4 secs. when the prism illuminator, was used.

The test specimen was a lamellar pearlite of 0.90 per cent. carbon content, polished in bas-relief on parchment.

2. *Arc lamp and incandescent lamp.*

Fig. 1 gives the specimen at a magnification of 1,200 (arc lamp; immersion apochromatic f = 2 mm., Num. aperture 1,30; projection eye-piece Nr. 2; camera length 65 cm.).

In Fig. 2 a "Half-Watt" incandescent lamp of 60 c.p. was used; of course, several advantages are obtained by a less intense source of light. The exposure had to be prolonged 36 times, to 12 min.

The optical quality of Fig. 2 is still good, but the definition is impaired by a general want of sharpness due to vibration during the long exposure.

It must be pointed out, however, that under quieter conditions photographs were obtained with the incandescent lamp of the very highest sharpness, which in no respect differed from Fig. 1. This proves that the *candle power of the lamp has no influence on the image quality*—a point which, though very natural, scarcely has been proved so far as yet.

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* C. Benedicks, *Metallurgie,* Vol. 6, p. 320, 1909.—Dr. W. Rosenhain made some remarks in the same direction in *J. Iron and Steel Inst.,* 1906, II, p. 180 (*see Metallurgie,* Vol. 8, p. 136, 1911).

The mirror reflecting arrangement provided with the camera proved to be of value, especially at long exposures, as it provides the possibility of a control of the proper focussing during a long exposure, without having any disturbing effect.

3. *Influence of vibrations and its avoidance.*

Even at short exposures with the arc lamp the sensitiveness for vibrations is very undesirable. The whole instrument being very rigidly constructed, the cause of this sensitiveness was by no means obvious. After a detailed examination, it was found that the comparatively great mass of the tube-carrying upright, with the two tubes (ocular and photographic), illuminator and objective, was responsible for the vibration sensitiveness. The remedy was possible to indicate: the objective is to be mounted by itself, on a special upright with little mass, and must have no direct connection with the tubes; if this be the case, then the inevitable vibrations of the tubes will be of no direct influence on the distance between objective and specimen—which is the most sensitive point as regards sharpness. A slight disadvantage introduced by this modification is that the distance between the illuminator and the objective will be subjected to small changes; these, however, seem to be of little consequence in comparison with the considerable increase in insensibility to vibrations which probably will result. Of course, even in works laboratories it is important to be able to produce good high magnification photographs without too much trouble.

In this connection the following may be added.

If the ground of the laboratory is not sufficiently free from disturbance it is necessary to mount the apparatus on some vibration-damping device. Now, it has been found from investigations executed in this laboratory by I. Malmborg* that the simplest thing is to mount the instrument on a solid plate, resting on a thick layer of felt; this, however, must not, as is ordinarily the case, be used in a dry condition, but moistened with a viscous liquid, such as vaseline. The energy of the disturbances is then absorbed through the forced motion of the liquid in the interstices of the felt. This method has been used with great advantage.†

4. *Disposition of diaphragms.*

In the metallographic microscope the cutting off of side-rays by diaphragms is well known for several reasons to be of great importance. As a general principle it can be said that the beam of light is to be reduced as much as possible without interfering with the intensity and uniform distribution of the light, or with the necessary extension of the image.

Fig. 3 gives diagrammatically the illuminating arrangement. In order to work properly, the image of the source of light—as which the opening of the diaphragm B is to be considered—must fall on, or at least near, the illuminator P, and the image of the iris diaphragm I must fall on the surface of the specimen T. The first item, brought about by the lenses L and F, is necessary in order to be able to use the whole of the light power available, and

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* *Ann. d. Physik* (4), Vol. 44, p. 337, 1914.
†Benedicks, *J. Iron and Steel Inst.* 1914. I, *p.* 407 (424).

to obtain a systematic centering of the light; the second item, effected by lens F and objective O, is necessary in order to limit properly the image on the plate, and to cut off false light so far as possible.

There is, in our view, no reason why the parts of this optical system should be differently arranged (sliding of L) when using a plain glass reflector or a prism reflector; nevertheless, on the microscope examined, as well as on other Continental microscopes, such a difference has been introduced intentionally. As a matter of fact, it was found quite practicable to obtain correct results, so far as the illumination is concerned, with both kind of reflectors, without any variation in the position of L (lens F had to be changed).

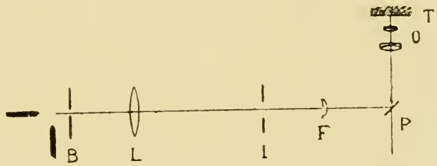

FIG. 3.

5. *Comparison between Le Chatelier prism and 45° prism.*

The Le Chatelier prism being so constructed that the lens F is formed in the same piece of glass as the reflecting surface P—which, in fact, is made up of two planes giving successive reflection—it was to be expected that it would produce sensibly better contrasts than a 45° prism with separate lens F, as in this case more reflections must occur.

A careful comparison was carried out. The result was that it was not possible for us to trace any difference in the working of the two kinds of prisms: the 45° prism is practically, so far as contrasts are concerned, not at all inferior to the Le Chatelier prism.

All comparative experiments were so made, by a special projection arrangement, that both prisms (or metal mirror) were exactly in the same position, covering the half of the back lens of the objective.

It was found that for lower magnifications than with the apochromatic f = 2 mm., the Le Chatelier prism has a decided advantage over the 45° prism in so far as it is not necessary, for obtaining a uniform illumination, to cover so much as half of the light area with the Le Chatelier prism as with the 45° prism. Thus at lower magnifications the aperture is better utilised with the Le Chatelier prism. The arrangement mentioned above serves the purpose of easily obtaining for each objective the proper position of the prism.

6. *Influence of the aperture.*

As already remarked, it has been pointed out by Dr. Rosenhain and by one of the present authors that the definition of the image at high magnification is considerably lessened when half of the aperture of the objective is covered by a prism or by an opaque

mirror, the resolving power being reduced to one-half in the direction at right angles to the mirror edge.*

This fact is amply borne out by our new comparative experiments. Thus, Fig. 4 shows the very best definition to be obtained with a prism illuminator. A comparison with Fig. 1, which was obtained with the plain glass illuminator, gives evidence of the much higher quality of the image obtained in the latter case, thus laying stress on the fundamental condition for obtaining sharp high magnification micrographs: the *full utilisation of the aperture of the objective.*

7. *Comparison between prism and metal mirror.*

It is obvious that with reflecting glass prisms—as well the Le Chatelier as the 45° prism—inner reflections cannot be entirely got rid of. On the other hand, with a metal mirror, such undesirable reflections do not occur, and it is to be expected that the contrasts will improve.

As the result of some direct comparisons, it was actually found that an indisputable, though slight, increase of the contrasts was to be seen on the micrographs obtained with the metal mirror. Thus, a metal mirror illuminator may be of some use whenever particularly strong contrasts are desired.

8. *Influence of the thickness of the plain glass.*

The glass slide provided with the microscope used was 0.45 mm. thick. It may be questioned whether this thickness, on account of the astigmatism introduced, is not too high. On using a very thin glass, 0.10 mm., as a matter of fact, a slight improvement of the sharpness occurred; this, however, was so insignificant that practically the use of the thicker glass must be considered to be quite justified.

If one is at liberty to choose, a thinner glass, of course, should be preferred to a thicker.

9. *Astigmatism introduced by the right angle reflecting prism.*

It seems by no means excluded, that sensible astigmatism could not be introduced by the right angle prism used in the Le Chatelier microscope in order to reflect horizontally the vertical beam of light issuing from the specimen. However, the excellent definition obtained, as in Fig. 1, shows that this undesirable influence of the prism can be entirely neglected. Of course, it is essential that the prism be of a very high optical finish, and carefully adjusted.

10. *Platinised plain glass illuminator.*

As pointed out on an earlier occasion,† it might be possible to increase the light intensity obtained with the plain glass illuminator by using a thin silver or platinum coating. Obviously, the thickness of the metal layer must not exceed a definite value; otherwise a decrease of intensity will result.

* *See* for instance Dr. Rosenhain's *An Introduction to the Study of Physical Metallurgy,* London, 1914, p. 52.

† C. Benedicks, l.c.

Fig. 1.
Plain glass illuminator, Arc lamp ; 20 secs. × 1200

Fig. 2.
Plain glass illuminator, "Half-Watt lamp" ; 12 mins. × 1200.

FIG. 4.
Le Chatelier prism illuminator, Arc lamp ; 4 secs. × 1200

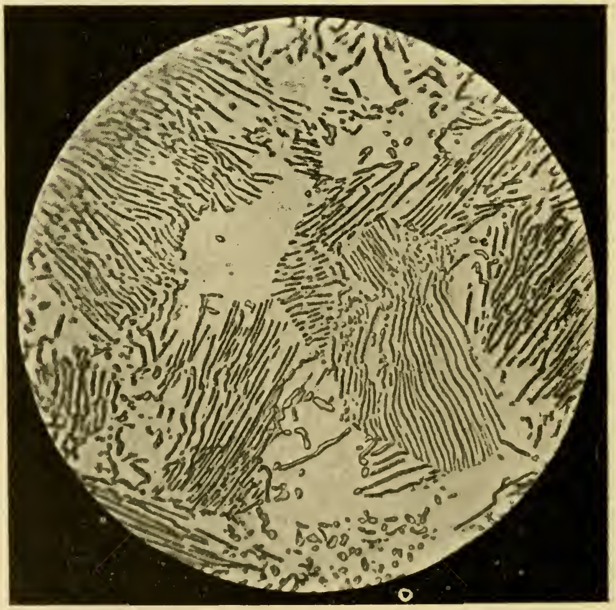

FIG. 5.
Plain glass platinised, Arc lamp ; 20 secs. × 1200

Fig. 5 reproduces a micrograph obtained with a platinum layer of a definite thickness, scarcely providing any appreciable increase in light intensity; exposure 20 secs., as in the other cases. A somewhat thinner coating might have been desirable.

It is of interest to note, however, that the micrographs obtained in this way were characterised by an unusually large extension of the sharp image. The contrasts seem to be somewhat weaker than those obtained with the other illuminators, and possibly this is the reason why on Fig. 5 (in original) are to be seen details, *e.g.*, some characteristic irregularities in the ferrite ground mass, which scarcely are to be seen on any other of the micrographs taken.

Thus it was found from these experiments that any essential gain in light intensity is difficult to obtain by platinum coating, but on the other hand a more detailed investigation is required to find out whether the filtering of the light on passing through the thin metal coating might possibly be of some advantage when it is a question of bringing out a maximum of detail.

11. *Further remarks.*

It has to be added that every exposure was repeated several times, and found consistent with similar experiments, so that, notwithstanding the obvious difficulty of avoiding focussing errors, the results obtained appear to be quite reliable.

A detailed account of these investigations has been published in Swedish in *Bihang till Jernkontorets Annaler*, Vol. 19, p. 537, 1918.

A detailed account will also probably appear in *Zeitschrift fur Wissenschaftliche Mikroskopie.*

Summary.

The investigations were started as a detailed and critical examination of the new Reichert microscope, which is of the Le Chatelier type. It was found to produce excellent results at the very highest magnifications.

Then some points of a more general character were examined, as:

(1) The using of an arc lamp (350 c.p.) or of an incandescent lamp (50 c.p.) gave exactly the same result.

(2) A modification of the microscope is proposed in order to diminish its vibration sensitivity.

(3) The proper arrangement of the diaphragms is discussed.

(4) A Le Chatelier prism and a 45° prism give at high magnification exactly the same result.

(5) A metal mirror gives slightly better contrasts than a prism.

(6) In the plain glass illuminator a thickness of 0.45 mm. does not injure sensibly the image quality.

(7) A slightly platinised glass illuminator gave somewhat finer details than any other illuminator used; this question, however, needs further research.

AN ORDINARY MICROSCOPE ADAPTED TO METALLOGRAPHY.

By F. Ian G. Rawlins, F.R.M.S.

The purpose of the following brief note is to draw attention to certain details of a more or less minor nature, which, when incorporated into an ordinary microscope stand, render it decidedly efficient for metallographical work, where an elaborate outfit is not desired. Although post-war models are now appearing by the leading makers for this branch of microscopy, there is a decided advantage in being able to use an ordinary stand, and the expense involved in the modifications is very moderate. Lastly, the additions are such that they can be easily carried out, even in the present abnormal state of the trade; and they are no detriment to work on transparent objects.

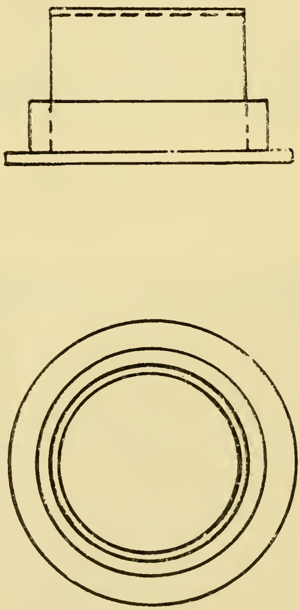

Fig. 1.

Vertical and Horizontal Sections of Plug.

(1) *Substage Fitting.*

The point of this is to overcome the trouble inherent in the use of ordinary stands for opaque objects with the vertical illuminator, *i.e.*, that on re-focussing, the centering of the illuminator and light-source is disturbed. Assuming that the stand possesses no substage apparatus (apart from the mirror), a focussing substage is fitted, provided with coarse adjustment, rack and pinion. Instead of the usual condenser, a solid brass plug (circular, and of the shape

sketched in vertical section,) is inserted into the ring. The top is provided with a slightly bevelled edge, into which fits a glass slip on which the plasticine holding the specimen is placed as usual. This can then be focussed upwards and downwards, avoiding any movement of the body-tube. To substitute another specimen, all that is needed is to rack down, swing the fitting out of the optic axis, take out the plug, insert another levelled specimen as already described, re-insert the plug, and focus as before. Of course, if only objectives are being changed, the focus can be re-set at once. An adapter fitted to the body-tube may be wanted if the rackwork on the stand is limited. The central aperture in the stage is generally too small, and should be enlarged for these additions. In the event of transparent work with condenser, polariser, etc., being contemplated, the focussing substage is ready at hand, the appropriate fitting being substituted for the afore-mentioned plug.

(2) *Objectives.*

Mounting in short barrels is very desirable for use with the vertical illuminator. There is often considerable difficulty in obtaining objectives so arranged from the makers. The following alteration, easily carried out, may assist. The lower part of the barrel is

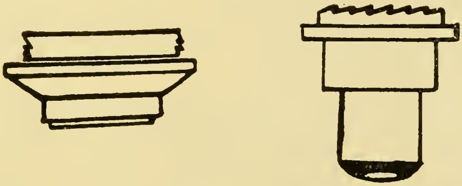

Fig. 2.

Carrier and Unscrewed Part of Objective.

unscrewed, and then inserted into a carrier bodily, which latter is provided with a standard thread, attaching to the vertical illuminator, and bringing the back lens of the objective very close to the reflector. Two lenses so treated, a $\frac{1}{3}$ inch and a $\frac{1}{6}$ inch, in the writer's possession give excellent results in practice.

(3) *Illumination.*

A type of "Half-Watt" lamp made in Holland has been found admirable. The 200 candle-power size is amply sufficient. By noting that the ring-filament in these lamps gives a very solid and concentrated area of light, and using a bull's-eye condenser of small aperture, it is possible to get effects closely resembling a "point-source" of light. The very moderate cost of these lamps compared with, say, a "Pointolite," is greatly in their favour, and they are quite powerful enough for magnifications up to 600 diameters in metallography.

In conclusion, apart from general ideas, the author disclaims any question of having originated the above improvements. His thanks are due to Messrs. H. F. Angus and Co. for their skilled assistance.

THE MICROSCOPE IN METALLURGICAL RESEARCH.

By E. F. Law.

It would be difficult to over-estimate the importance of the part played by the microscope in metallurgical research during the last 15 years. Its introduction threw a flood of light on problems hitherto unsolved, and it was not surprising that the early work of the pioneers—Sorby, Osmond, Roberts-Austen and others—was followed by a rush of eager recruits anxious to take part in the campaign. Nor was it surprising that this display of zeal should be followed by a lull, if not an actual reaction; such periods invariably follow a period of exceptionally rapid progress, and when they occur it is wise to take stock of the existing position and endeavour to prepare the way for the next advance. With that object in view we may briefly consider the metallurgical problems which have already been solved by means of the microscope, and then turn to some of those which are awaiting solution and which require either more knowledge or more perfect instruments.

Problems Solved.—Before the introduction of the microscope we knew from the chemical analysis of an alloy its ultimate chemical components, but we did not know in what form those components occurred. Probably the only exception to this rule was to be found in the case of carbon in cast iron, which was invariably divided into free or graphitic carbon and combined carbon. The microscope altered all this, and explained not only the relationship between the structure of the alloy and its mechanical properties, but the structural alterations and consequent changes in mechanical properties produced by heat treatment.

Problems to be Solved.—With very few exceptions, it may be said that the finer or smaller the structure of an alloy, the more useful it is from a commercial standpoint; and it frequently happens that the best of our commercial steels possess so fine a structure that they are imperfectly resolved by the highest powers of the microscope now available. How often do we read in descriptions of microstructures such expressions as "a confused groundmass" or "a matrix whose structure is not resolved by the microscope"? Another problem awaiting solution is to be found in the intercrystalline weakness of metal. During the last few years a wonderful edifice of hypotheses has been erected on the foundation of a so-called amorphous phase which is said to exist between the crystals of a metal, and this amorphous material is made to serve as an explanation either of its strength or weakness.

Unfortunately, there is very little direct evidence in support of these theories; but with a higher degree of magnification it is possible we may learn more of the intercrystalline structure of metals. Even of the crystalline structure we know very little, and there is scope for much research on the "dendritic" structure which is shown on heat-tinting, and which has been so beautifully developed by Humfrey.

For these and other investigations we require instruments which will give us a higher degree of magnification, and we look to the manufacturers for their assistance. But, if we are provided with such instruments, we, on our part, must be prepared to supply a much higher degree of skill in the preparation of samples for examination than is commonly met with.

DEVELOPMENT OF THE METALLURGICAL MICROSCOPE AND ITS SUGGESTED APPLICATION TO SOME UNSOLVED PROBLEMS.

By HERMAN A. HOLZ, NEW YORK.

Every step forward in the development of apparatus for metallurgical research work is followed by an increase of our knowledge of the particular field of metallurgy for which the instrument serves. In other words, suitable apparatus have to be developed to a high stage of perfection before we can make accurate and reliable determinations which enable us to gain valuable knowledge of certain facts which were unknown to us before or about which we were not quite certain.

The development of the thermo-electric pyrometer by Le Chatelier enabled us to find the transformation regions in steel, Sir William Roberts-Austen's apparatus—making use of thermo-electric forces—permitted us to determine these transformation regions with great accuracy and in a convenient manner, resulting in systematic research work which forms the basis of the art of heat-treating steel.

The most important apparatus which enable the metallographist to find the way towards improvements in the structural details of steel and to control the correct thermal treatment to which he subjects the material, are the microscope and the permeameter. The microstructure of steel can be observed and photographed by means of the microscope, while it can be measured and expressed in definite figures by means of the permeameter, thus permitting quantitative determinations. The success gained in recent years in obtaining higher efficiency from definite alloys, especially alloy steels, and in developing steels and bronzes of greater strength, has been due to systematic metallographic, especially microscopic, research work.

As the methods of microscopic investigation have been improved by the development of more efficient etching processes, so have the design and construction of metallurgical microscopes been gradually developed to a high stage, in regard to the quality of lenses, source of light, vertical illuminators, etc., as well as to rigidity and usefulness of mechanical arrangements. While the pioneer work on the microstructure of metals was carried on by means of ordinary (bacteriological) microscope stands, it was soon found that the investigation of opaque substances, without using cover glasses over the object, necessitated changes in the illuminating system and in the grinding and mounting of the objectives. The vertical illuminators now largely used for this purpose were developed in England (45 degree plane glass reflector by Beck) and France (prism reflector by Le Chatelier, first made by Pellin and Nachet). The objectives used in connection with these illuminators have to be mounted as short as possible; the nearer the reflecting surface stands

to the objective, the more even is the illumination obtained. In the method of plane glass reflection, the rays of illumination and of the image penetrate the entire objective simultaneously; the final image suffers somewhat thereby, and does not appear as sharp as with the prism illuminator. This disadvantage can be remedied somewhat by decreasing the opening angle of the objective. The important advantage of the 45 degree plane glass illumination is that the light strikes the etched surface at exactly 90 degrees, so that with the highest magnifications and in working with very fine, slightly etched specimens images richer in detail and free from spectral colours are obtained; the rays of light are, in this case, uniformly distributed over the entire field covered by the objective. In applying the Le Chatelier prism illuminator, one half of the objective serves for illuminating the specimen, the other half for producing the image. This arrangement offers the advantage that by dividing the function of the objective the formation of reflexes is reduced and the full angle of opening of the objective is utilised. The images thus obtained are clearer and sharper, of special advantage in photography. On the other hand, fine details of structure may be lost through the one-sided illumination striking the etched surface at an angle. Since both forms of vertical illuminators possess certain distinct advantages and disadvantages, it will be found very convenient to be able to change quickly from one to the other, and to select the one which will give the more satisfactory image, depending upon the nature of the microstructure under investigation and upon those points that the metallographer desires to bring out more prominently in his micrographs. The latest metallographic outfit brought on the American market by my firm possesses this important feature of "selective" vertical illumination.

Many of the steel works' metallographers prefer now the inverted form of microscope, first designed by Le Chatelier and first made by Pellin. I desire to mention here that the original Le Chatelier-Pellin outfit carried a stage supported on one point only, which was easily bent out of focus, and did not possess sufficient rigidity. Le Chatelier designed in 1911 another and very much improved inverted stand, also made by Pellin, which carries a firmly supported stage and which was imitated by German and Austrian manufacturers. Nevertheless, the largest number of German steel works, amongst them the Krupp works, preferred the new Le Chatelier-Pellin stand which was marketed in 1912 and 1913 with much success in Germany by Dujardin, who imported the microscopes from Paris and fitted them with Zeiss apochromatic objectives, thus combining best mechanical design with good optical equipment.

Returning to the question of metallurgical microscope stand design, I want to say that the popular form of inverted stand really has only the one advantage of eliminating the necessity of levelling the specimen, and this advantage disappears mostly in using an oil immersion lens. The disadvantages of the inverted stand are the limited field which can be observed, the large leverage of the stage resulting in magnification of vibrations, and the impossibility of working with daylight. Microscope stands have been successfully designed (Félix Robin's outfit, formerly made by Collot, Paris), which combine the advantage of horizontal camera with firmly sup-

ported stage below the objective, thus permitting the convenient investigation and photography of heavy specimens, observation of their edges, use of daylight, and large reduction of vibrations. While these outfits are not available any longer, it seems to me that the development of satisfactory photomicrographic apparatus for metallography should follow this general design, and not the inverted design, which possesses several disadvantages more important than its one single advantage.

Amongst other microscopic problems awaiting further development, besides higher magnification, are: the utilisation of polarised light for metallographic investigations and the application of kinematographic work to the study of structural changes in metal sections exposed to mechanical stresses or varying temperatures. The pioneer work in solving the apparatus development problems for these studies has been successfully carried out, and the high value of such investigations will be appreciated. It is to be hoped that research workers will take up systematically this work, which has been successfully started. Further microscope development, offering no more difficulties, will be in the direction of stereoscopy. We are born with two eyes, and used to see with both of them; mon-objective binocular microscopes, for work with the highest magnifications, have been successfully developed, and there seems to be no reason why this instrument development should not be applied to advantage to metallographic practice. I believe that the near future will see a large extension in the use of binocular optical instruments.

I would not like to omit here to mention some important progress made in Great Britain in the development of metallographic equipment: The Edison-Swan "Pointolite" (tungsten arc) lamp, which is the ideal source of light for photomicrographic work, and the Wratten and Wainwright light filters and special plates for photomicrography. These products represent the best that has ever been developed in their respective lines, and every metallographer will find the use of these appliances extremely valuable in his work.

In ending my contribution, I want to make a few additional remarks about the importance of "magnetic analysis" in metallographic research and routine work. The use of higher magnifications in microscopic investigation will most probably lead to valuable results, although we must always remember that the higher we magnify the less we see, *i.e.*, the field of observation is getting smaller with the use of objectives of higher powers. Magnetic analysis (the accurate determination of the various magnetic properties of iron and steel by means of a standard permeameter) enables us to draw distinctions between steels where the present methods (microscopic, hardness, tensile tests) fail to make differentiation. Microscopic investigation of steel gives results which are qualitative, rarely quantitative. The preparation of micro-sections often releases stresses in the metal to be studied, and, in general, tests of this kind require a great deal of individual judgment and experience. Magnetic data permit quantitative measurements of the state of micro-structure and the interpretation of test data leaves no room for conjecture.

Such magnetic investigations can be carried out successfully only by means of a perfectly reliable permeameter and only by determination of *all* the magnetic characteristics of the material under investigation. Permeameter equipment has been recently developed to a high stage of perfection, combining simplicity of operation with perfect accuracy of measurements (Fahy Simplex Permeameter), and since then the application of magnetic analysis to metallographic investigations has made rapid progress in the United States. It is to be hoped that British metallurgists will apply this excellent method to the solution of their problems, and will co-operate with American research workers, to considerable mutual benefit.

General Discussion.

In inviting **Dr. W. H. Hatfield** to offer some remarks on the metallographical side of microscopy, the Chairman suggested that in view of the short time available for general discussion of the many important papers presented on this subject, the discussion be continued at Sheffield, and, if possible, also at Glasgow.

Dr. W. H. Hatfield: I should like to say that I know I should be expressing the general feeling of the Council of the Metallurgical Society at Sheffield in saying that we have great pleasure in accepting your invitation. If you will let us have copies of these papers, particularly the metallurgical section of them, we will have them thoroughly discussed, and, if you desire it, we will send Mr. Spiers a copy of the discussion.

Speaking on the papers, I think one can safely say that we have in Sheffield many large firms who have well equipped laboratories where these different types of microscopes are in use every day. I should like to congratulate the President on the interesting paper by Mr. Elliot and himself. I think that the work contained in this paper typically represents what we are able to do with the microscope in our study of steel. We (Brown-Firth Research Laboratory) have some photomicrographs upstairs; they are really on the same lines as those of Sir Robert Hadfield, but we have gone as far as 8,000 magnifications. I think Sir Robert will probably agree with me when I say that 1,000 diameters really represents the limit of adequate resolution which we are able to obtain in our general practice, and that if we go in for these higher so-called magnifications—I refer both to his illustrations and to ours—we are getting enlarged pictures, but we do not obtain really much more information as to the structure of our materials, and from that point of view it is interesting to refer to the paper on Dr. Sorby which the President has put before us. I notice there that Sorby made great advance in the 'eighties because he was able to use sufficiently high magnification to see the structure of the pearlite. Every time that we have been able to get a still higher resolution we have obtained more fundamental knowledge with regard to steel, and whilst I feel that 1,000 is at present our practical limitation, I am certain that if only you experts in the construction of the microscope can go still further, we shall obtain still more fundamental information. For instance, I remember studying what we know as black steel at 250 to 500 diameters, but we got inconclusive information, but as soon as we got to 1,000 diameters we had definite information and a complete solution of our difficulty. There are two problems which I would like to point out to you microscopists, or rather to the makers of microscopes, which are awaiting solution. One Dr. Aitchison deals with very ably in his paper, *i.e.*, notched bar brittleness. I

will not go into it except to say that there are two fundamentally different conditions of the same steel, which at present we are not able to obtain the reason for by means of the microscope, and I think we have a right to feel that we should. I do not hesitate to make a confession to you. An artilleryman does not worry unduly as to how the gun was made or who made it. I represent exactly that type of scientific investigator who uses a microscope, and, like the artilleryman, I am telling you what we would like to do with the gun. Therefore, I think it is up to the makers of the microscope to help Sir Robert Hadfield and many people like myself who are engaged in these investigations, out of our difficulties. In conclusion, I would tell you that all metallurgists, whether they be working on steel or non-ferrous metals—brass, copper, gold—are faced with the difficulty of obtaining an adequate solution as to the cause of the effect of cold work on metals. We discuss the amorphous theory; many of us believe in it; we ought to be able, by means of the microscope, if you will give us a suitable tool, to obtain an adequate solution of that problem. Why has cold work the great effect it has in hardening metals? Gentlemen, I consider the solution of that problem is awaiting the excellence of your products.

The following contributions have been received to the discussion on the paper by Sir Robert Hadfield and Mr. T. G. Elliot.

Mr. A. T. Adam and **Mr. F. S. Merrils**: In studying the microstructure of steel wires we have found it necessary to employ high magnification. The difficulty in resolving the structure of carbon steel wires is due in the first place to the nature of the chief constituent in properly heat-treated wire, viz., "Sorbite," or "Sorbitic pearlite," and secondly to the minuteness of the structure caused by cold work.

Some time ago we were fortunate in securing a very good Leitz 1/12 in. oil-immersion achromatic objective, N.A. 1.3, which has enabled us to obtain sharp photographs of wire up to a magnification of 2,500 diameters. This we have found to be about the highest magnification at which good definition and detail are retained with this objective. In certain special cases we have gone up to about 5,000 diameters with distinct advantage.

One of the contributors, being engaged in an investigation on "The Relation of Heat Treatment to Cold Work," has found these photographs of great service in illustrating the effect of cold work on the structure, and hopes to have them published in the Carnegie Scholarship Memoirs of the Iron and Steel Institute this year.

It is admitted that there is a certain loss of detail in these photographs as compared with visual examination, but this detail is lost in any photograph where an ordinary eye-piece is used. On the other hand, certain features which are barely visible in a photograph at, say, 1,500 diameters, are more pronounced in the enlargement obtained by increased camera length.

In view of these attempts at high power photomicrography, we are therefore extremely interested in the authors' work in this direction, and we are in entire agreement with them in the belief that there is a great field for further exploration in this direction.

One or two examples of photomicrographs at high magnification are given below with details. The source of illumination used is a tungsten arc 500 candle-power "Pointolite," made by the Edison Swan Electric Co., Ltd. With this source of light it is only necessary to use a single condenser to focus the image of the incandescent arc on to the plain glass illuminator. It may be of interest to add that Wratten and Wainwright colour filters, M series, were used with Wratten M Panchromatic Plates in taking these photographs.

Fig. 1 shows that it is possible to obtain good definition in a photograph at this magnification. The subject is possibly not one that requires high magnification in itself, but it is useful for purposes of comparison with subjects that do require such magnifications, *e.g.*, Fig. 3.

Apart from this, it appears to show that "pearlite" is a more complex constituent than lower power photographs indicate. The contributors have always considered the idea that "pearlite" is constructed of alternate layers of ferrite and iron carbide completely

separated, to be rather vague. This photograph suggests that complete separation has not taken place in the laminated form, and occurs only in the spheroidised form; *e.g.*, Fig. 2.

The appearance of sub-laminations in Fig. 1 is not a false effect due to excessive cutting down of the iris diaphragm, as no diaphragm was used in this instance. A slightly false effect, due to this cause, is evident in Fig. 5, which was taken expressly for this contribution.

Fig. 3 shows a subject in which the laminations are too fine to be clearly photographed at a magnification of 1,500 diameters. The photograph demonstrates that even air cooling a rod about $\frac{1}{4}$ in. diameter is not sufficiently rapid to arrest the partial production of "pearlite." It will be noticed that the constituent which we have called "sorbitic pearlite" is partly cellular.

The difference between these structures is not apparent at lower powers.

Fig. 4 is to be compared with Fig. 5. In spite of the slightly false effect in the latter, caused by the iris diaphragm, it draws attention to the existence of a feature which might easily escape notice, but which is apparent on closer examination, in Fig. 4, namely, the sub-laminations.

Mr. **Henry M. Sayers**: These photomicrographs of steel at 5,000 and 8,000 diameters are very fine, and testify to the skill and patience of the authors. They confirm the accepted theory that no new details can be revealed by magnifications incommensurate with the N.A. of the objective. With an N.A. of 1.4, 1,000 diameters shows all that can be seen, but, of course, greater amplification may be useful for diagrams to be displayed to large numbers of people, at once, just as lantern slides are magnified by projection.

The authors state that the illuminant used was a 20 ampere alternating current arc, the arc being focussed on the stop or aperture of the vertical illuminator. Presumably one or other of the carbons was so focussed. This adds to the merit of the work, for certainly an A.C. arc is less satisfactory in intensity and form of the radiant than a C.C. arc crater.

It will probably be found that one of the larger tungsten arc lamps is better than an A.C. arc. It is true that the tungsten arc requires continuous current, but this can be got from an A.C. supply with a simple form of auto-transformer and rectifier. A nominal 100 c.p. Pointolite, taking about $1\frac{1}{4}$ amperes, gives satisfactory negatives of steel with 5 minutes' exposure, at 1,200 diameters, using a light filter denominated "5 times," and Wellington "Anti-Screen" plates.

The Pointolite lamp is somewhat more convenient for the necessary source emplifying lens system than an arc. The exposures above mentioned were taken with a combination which magnified the source about three diameters, giving a field of 3 in. diameter, *i.e.*, comfortably filling a quarter plate. With no amplifier the field on the plate was only about 1 in. diameter. Greater amplification can be obtained if required by varying the lens distance of the combination.

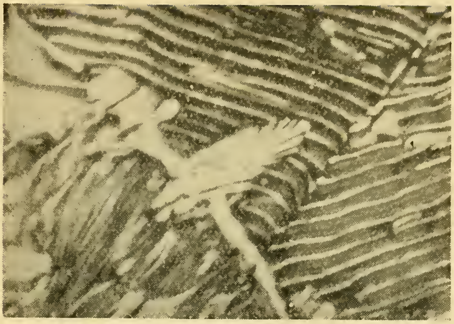

FIG. 1.

1.2 per cent. Carbon Steel, annealed. Magnification 5,000 diams. approx.
K.1 Colour Filter.

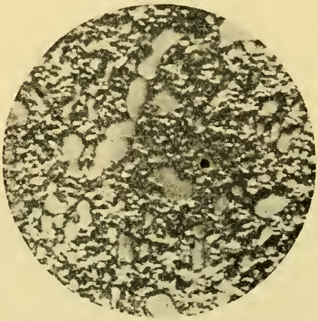

FIG. 2.

1.2 per cent. Carbon Steel Wire. Re-heated at 650° C., showing Spheroidised Cementite. Magnification 4,000 diams. approx. Red Colour Filter A, showing maximum detail.

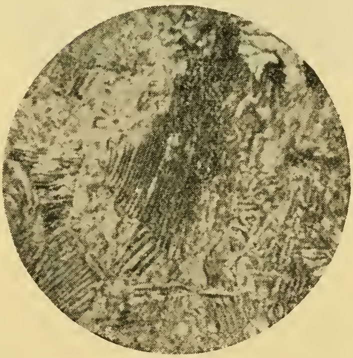

FIG. 3.

900° C., showing Sorbitic Pearlite. Magnification 3,000 diams. Orange
0.85 per cent. Carbon Swedish Steel. No. 5 S.W.G. Rod. Air-cooled from
Colour Filter G.

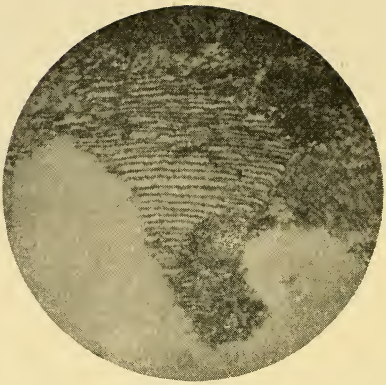

FIG. 4.

0.5 per cent. Carbon Steel Bar, annealed. Magnification 1,500 diams. Red Colour Filter A.

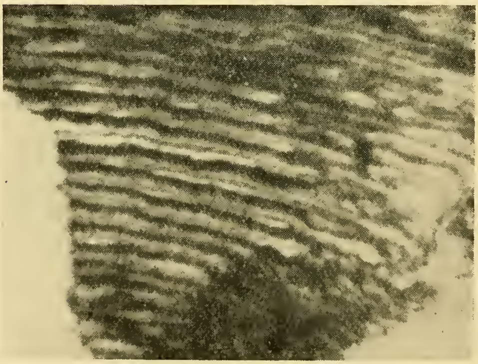

FIG. 5.

Portion of same field. Magnification 4,500 diams. K.1 Colour Filter.

NOTE.—These reproductions have been reduced by one-third from the original photographs.

Professor H. M. Howe (*communicated*).

All our present conceptions of the nature of alloys are due to the microscope. The labours of Sorby, of Osmond, and of Le Chatelier, brought us to the point at which we recongise pearlite as an eutectoid, the great turning point in the progress of our conceptions.

One finds important problems solved quickly and surely by means of a magnification of 2,000 which completely baffled us when our magnification was confined to 200 diameters. Thus, just as the first step of slight magnification opened up a new world to us, so a second step has brought new and important conceptions of great potential service.

Have we not good reason to hope from the past that like important knowledge awaits further increase in our powers of magnification? Have we not every reason to believe that this knowledge is there to-day, behind that closed door, awaiting its unlocking by him who shall devise the key? No doubt the technical difficulties are extreme, but surely the reward which awaits success should be proportionally great.

A group of papers, presented and taken as read, discussed various other aspects of the microscope, its use and applications.

THE MEASUREMENT OF GRAIN SIZE.

By Zay Jeffries, Cleveland, Ohio.

Just as the telescope has given us certain information in astronomy which we know no other way of obtaining, so the microscope has permitted us to obtain direct knowledge concerning many things unresolvable with the naked eye. Much of the knowledge gained with microscopes would not be obtainable in any other way. For example, the quantitative determination of grain size of fine grained metal is only possible because of the microscope. The purpose of this brief note is to point out a case in which chemical analysis varies but little, and success or failure depends on the grain size which can be determined only with a microscope.

In the mechanical working of tungsten it was found that some lots of metal would work well, and some only with great difficulty. Sometimes the metal would be so hard that it could not be drawn to the smaller sizes; it would either break too frequently or the die wear would be so great that it could not be tolerated. A careful study of these materials was made from both chemical and physical standpoints. The chemical analysis was found to be so nearly constant that errors of analysis would mask any differences which might actually be present. It is not maintained that slight differences in analysis did not exist, but only that the determination of the impurities which, aside from thoria, probably did not exceed 0.05%, gave no definite clue to the difficulty.

It was found that the variation in grain size was greater than the variation of any of the chemical or physical properties, and that the working properties varied with the grain size. The larger grains had more ability to stand extreme deformation than the smaller ones. On the other hand the tendency to break in the early stages of working was greater in the coarse grained material. If the grains were too small in the tungsten metal containing 0.75 per cent. ThO_2 the wires broke frequently in the smaller sizes and the die wear was excessive. In this metal the danger line is reached if the number of grains per square millimetre exceeds about 6,000. On the other hand, it is desirable that the tungsten metal have an inherent high resistance to grain growth to insure a long life in the lamps. This factor is usually satisfied if the number of grains per square millimetre exceeds 1,500. It is, therefore, desirable to control the grain size between 1,500 and 6,000 grains per square millimetre in the ingot.

In the early days of working tungsten no such control was exercised and lots of metal were encountered which were unworkable, and no one knew the reason. The inference now is that the ingots were too fine grained since it is possible to reproduce these results with fine grained metal to-day. A contributing, and sometimes the major cause of trouble was the failure to eliminate the oxide of tungsten, but even this is more readily detectable with the microscope than by chemical analysis.

Every lot of tungsten metal made at the Cleveland Wire Division of the General Electric Company is now tested for grain size; in fact, treated to give the proper grain size in many cases. The lots not falling

within the proper limits of grain size are not subjected to the working process, which costs on the order of twenty times as much as the preparation of the ingot.

The method of quantitatively determining the grain size has been described by the author in the *Transactions of the Faraday Society*.* A circle 79.8 millimetres diameter is drawn on a ground glass, and the image of the properly etched sample is brought into good focus. The grains intersected by the circumference of the circle are counted and multiplied by .5 (in the paper above mentioned this factor was given as .6, but later results show that .5 is both more accurate and simpler to use),† and this product is added to the number of grains completely included. The sum is the number of whole grains within the area represented by the circle.

It is true that the determination of grain size in other metals, such as alpha brass, has been used as a help to works control, but the application of this is not very extensive and not as necessary as with tungsten. Other differences are manifest which may be easier to determine than the grain size. Several metallographists have told the writer that they had investigated the variations in grain size and found that the physical properties did not vary greatly with considerable variations in grain size, and hence they had concluded that the test was not suitable for their purposes. It is for this very reason that the writer believes that many other special cases will arise in which a considerable change in grain size will correspond to but slight differences in certain other properties (like the working properties in tungsten), and these properties may be controlled within narrow limits by controlling grain size. In fact, metals or alloys other than tungsten have certain properties which can be controlled only by controlling grain size or other structural features, but these structures are produced by uniform processing determined by experience, and the actual quantitative determination of grain size is not necessary. With the modern demand for uniformity of product and high standards, the manufacturing tolerances will be reduced, and extended use of grain size control may be expected. Even now the defective loss in the mechanical working of metal could be reduced in many instances by properly controlling the grain size in the various stages of processing. In large plants the lessening of the defective loss a fraction of one per cent. would more than pay the cost of investigation and upkeep of these control methods.

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* Vol. XII, Part I, 1917, p. 40.

† Metallurgical & Chemical Engineering, p. 185, Feb. 15, 1918. Also Sano and Ohashi, Proc. of the Physico-Mathematical Society of Japan, 3rd Series, Vol. I, No. 7, p. 216, treat this method of grain size determination mathematically, and conclude that "Jeffries' formula . . . is quite sufficient for practical purposes."

NOTE ON MICROSCOPE MICROMETRY.

By Professor W. M. Thornton, D.Sc.

In the increasing use of the microscope by engineers for the measurement of small objects which cannot be dealt with by usual micrometric methods, the need is occasionally felt of a means of calibrating the eye-piece micrometer. For this purpose it is convenient to have a scale one centimetre long photographed on a glass slide, and divided into millimetres, half millimetres, tenths, hundredths, and possibly thousandths.

This is covered with a thin slip of mica or glass cemented on round the edges.

The object of this note is to call attention to the convenience of the combination of such a scale with a fully divided ocular micrometer as a means of calibrating rapidly and with sufficient accuracy for most purposes, any system of eye-piece and object at any extension, in microscopes not fitted with travelling micrometer stages. The idea is no doubt old, but enquiry over a wide area has shown that it is not in use by those making daily observations, and to engineers and physicists who are not in immediate touch with microscope theory and formulae it may be useful to have both a loose scale in the eye-piece and a graduated slide for calibration.

Dr. Maurice Langeron, Chief of the Laboratory at the Medical Faculty, Paris, presented the following papers on behalf of **Dr R. Bazin.**

MAKING ENLARGED-SCALE DRAWINGS AFTER BAZIN.

The device dispenses with a camera lucida, and consists of an ordinary biconvex lens A, giving a virtual, erect and enlarged image of the object OO, which is placed between the lens and its focus; Fig. 1 explains the arrangement. An image of the paper and of the point of the pencil C is formed on the plane on which the object rests, being produced by the plano-convex lens B of short focus; this image is real, reversed and reduced in size, because the paper is at great distance beyond the focus. The biconvex lens A enlarges both the small image of the pencil point and the object itself, which are in the same plane. In drawing one has merely to trace the outline of the image.

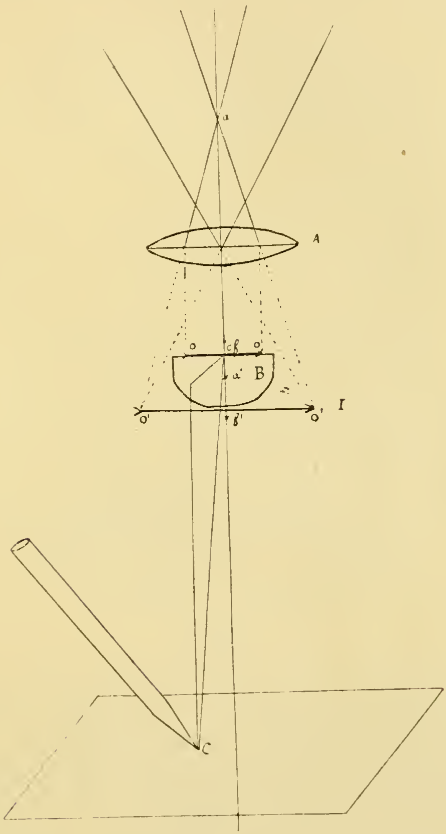
EYE-PIECE GRATICULE FOR DRAWING, MEASURING AND COUNTING.

(*Bazin's Réseau Oculaire.*)

When painters wish to copy a picture on a different scale, they divide the photograph of the picture, as well as the canvas on which they are going to paint, into small squares. Each little square is then filled up.

The réseau oculaire, or eye-piece graticule, consists of a plate on which lines, very fine, yet as distinct as possible, form a system of squares of 1 mm. size. This plate is placed on the diaphragm of the eye-piece.

In drawing one makes use of squared paper, and the microscopic image is reproduced in the way that the painter copies his picture. To facilitate taking measurements, one of the squares in the centre (see Fig. 2) is subdivided into four smaller squares, and one of the small squares is again subdivided in the same way, with the aid of a micrometer objective. Thus measurements can easily be made.



A. Biconvex lens
B. Plano-convex lens of short focus and o.o′ erect and enlarged
I. Vertical Image
O.O. Object

aa′ Focus of A
ff′ Focus of B
C. Pencil Point
c. Image of Pencil Point

FIG. I.

When particles are to be counted, the diluted blood or bacteria preparation is placed in some cell which need not be squared; the thickness of the cell must be known. It will be possible to count the number of globules approximately, provided that one can get them displayed in a single layer. The volume of the little drop adhering to the pipette being known, the area which the drop occupies can be measured with the aid of the graticule; by counting the mean number of red corpuscles per square, an approximate estimate

can further be formed of the number of elements containd in the drop. In the same way parasitic organisms and leucocytes can be counted.

The réseau also serves as a reference system of co-ordinates, and can replace the pointer of the eye-piece. (The device was described in the *Bulletin de la Société de Pathologie Exotique*, Vol. XII., p. 135, 1919.)

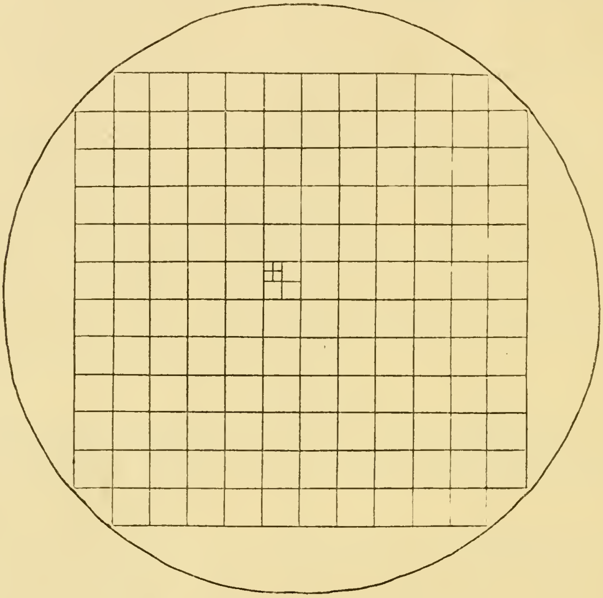


FIG. 2.

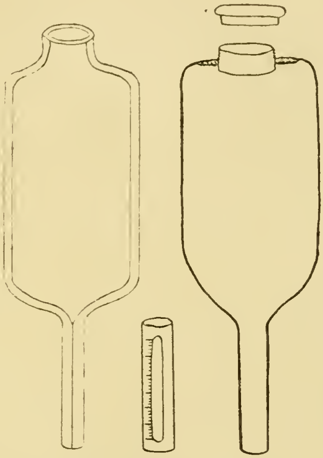
BAZIN'S CAPILLARY CHORESIMETER.

The haematocrite makes use of centrifugal force for the purpose of counting the number of blood globules. With a similar apparatus bacteria suspended in distilled water can be counted; their small size calls for a special device, however.

A glass flask, of a capacity of 20 cub. cm., is terminated by a capillary tube, 0.2 mm. bore, 4 cm. long. The extremity of the tube is closed by a rubber disc kept in position by a stirrup which can be turned about its axis (see Fig. 3). The stirrup is supported by a metal collar encircling the neck of the flask. The upper aperture of the flask is hermetically closed by a metal stopper, which is provided with a rubber packing and screwed into the collar. To prevent any slipping of the stirrup during the centrifugation, the capillary tube, together with the stirrup, is enclosed in a sleeve of copper or brass. The capillary tube is filled with distilled water, the rubber disc is applied to its lower end, and the stirrup turned down. The bacteria suspension is poured into the flask, the stopper screwed in, and the sleeve mounted. The apparatus is then placed in the container of the centrifugal machine, which is turned for ten minutes at 7,000 revolutions. The bacteria collect in the capillary

tube, and are watched through the two symmetrical slots in the sleeve. Measurements are taken with the aid of a vernier and a lens. The apparatus is calibrated with the aid of bacteria suspensions of known numbers.

The capillary tube should neither be too fine nor too coarse; in the former case the capillary might become clogged, in the latter the precision of the measurement would be impaired. The dilution



Flask and Capillary Tube — Graduated Brass Sleeve with Slot — Stirrup and Stopper

FIG. 3.

of the suspension must also be suitable, as a concentrated preparation would entirely fill the capillary. The distilled water used should carefully be filtered, since a small particle, *e.g.*, of cotton, would stop the tube. In order to facilitate comparative determinations, a standard tube containing a suspension of known titre, of particles of known dimensions and density, should be used; porphyrised kaolin may serve for this purpose, after levigation and filtration.

THE GRAYSON RULINGS

By Dr. A. E. H. Tutton, F.R.S.

It must have been with the deepest regret that workers with the microscope heard of the premature demise of Prof. H. J. Grayson, of Melbourne, the remarkably gifted maker of the well-known "Grayson Rulings." Those who have used the rulings have been struck with both their accuracy as regards spacing, and the extraordinary sharpness of each individual line, especially in the case of those on speculum metal. The truly wonderful guiding of the diamond point by the late Prof. Grayson's own unique master hand, no less than the perfect construction of his ruling machine, which enabled such accurate spacing to be obtained, have never ceased to impress those who have worked with these rulings. Their merit begins at the point where the other rulings so well known to us, such as those of Rowland and of Michelson, leave the field, namely, above 20,000 to the inch. His extreme rulings of 120,000 to the inch, are a direct challenge to the microscope, for they represent its highest resolving power. While these wonderful rulings, and those only a degree less impressive of 100,000 and 80,000 to the inch, are of great use to us in studying high resolution, with natural microscopic objects presenting detail of great minuteness, and also in actual calibration and measurement of the detail of objects of such extreme minuteness, it is probably with the more moderately spaced rulings of 60,000 and 40,000 to the inch that the most important work is to be done.

The writer has already called attention, in his memoir* to the Royal Society on the Interference Comparator for Standards of Length, to the fact that the Grayson rulings of 40,000 to the inch spacing are capable of becoming of great importance in metrology, as fiducial marks, the middle one of five such rulings forming an excellent signal-mark. For, as was pointed out in the memoir, the 40,000th of an inch is the wave-length of red light, very close indeed to the exact wave-lengths of the red hydrogen ($\frac{1}{38710}$ inch) or the red cadmium ($\frac{1}{39459}$ inch) line. Thus, the space between any two successive lines of the 40,000 to the inch rulings corresponds practically exactly to the passage of two interference bands (two complete interference-band spacings) in red hydrogen or cadmium light. That this is true of the late Prof. Grayson's rulings labelled by him as 40,000 to the inch, has been proved by the writer by direct measurement against the interference bands, on the Comparator at the Standards Department. These more moderately finely spaced rulings are admirably resolved by the 1/15th inch dry objective supplied for the purpose by Mr. Conrad Beck. The lines, indeed, as seen through the fine-movement micro-

* Phil. Trans., A., 1910, *210*, 30.

scope, are as clear as the interference bands in the interferometer of the Comparator, and the writer expressed hopes in his memoir to be able to carry out with their aid the determination, by this original method, of the exact number of red cadmium wave-lengths in the British Yard. Such a determination would, indeed, be quite simple and straightforward, with the proviso that an adequate supply of the rulings required for the stepping off process could be obtained.

The writer also hopes to use them as fiducial marks in connection with interferometric fine-measurement in general, and a General Interferometer, involving the same type of travelling fine-movement microscope as those (the pair) on the Comparator, is being constructed for him for the purpose at this moment.

The breaking out of the great war, and now the unhappy death of Prof. Grayson, have delayed the possibility of further work on the subject, and as doubtless other workers in high power microscopy are also at present unable to carry out their own particular researches for which the higher rulings are essential, the writer considers it desirable that the position shall be discussed at this Symposium of Microscopists.

The writer's suggestion is that the Symposium should address to the Governing Body or Council of the University of Melbourne a letter of condolence, expressing firstly the unanimous opinion of the great body of Microscopists and Scientific workers here assembled of the very great loss which the University has suffered by the demise of Prof. Grayson; and, secondly, the hope that the University will do all that is possible to ensure that Prof. Grayson's ruling machine shall still be available for the production of the "Grayson Rulings." It may be that Prof. Grayson had trained one or more members of his staff in his method, and if so it should not be difficult to arrange for the most highly desirable continued production of the rulings.

The writer took the opportunity of mentioning the matter to General Sir John Monash, the gallant Commander of the Australian Forces, and a member of the Governing Body and Council of Melbourne University, on his recent visits to London and Oxford on the conclusion of the War, and he kindly undertook to go into the question on his return to Melbourne. Possibly General Monash's relative, Dr. Rosenhain, whom we know to be interested so keenly in the subject from the microscopical point of view, and who has intimate connections with Melbourne and its University, will also be inclined to assist in carrying the subject further.

The continued production of the Grayson Rulings, especially those of the 40,000 to the inch spacing, is so important a matter that the writer has felt sure that the Symposium would wish him to bring it forward.

THE TESTING OF MICROSCOPE OBJECTIVES AND MICROSCOPES BY INTERFEROMETRY.

By F. Twyman.

My firm has no commercial interest in microscopes, and so far I have not succeeded in interesting any microscope makers in the methods of test I shall describe. We have, therefore, not done much more on the subject than to test a few microscope objectives, and these, although by makers of repute, not of high power. They show aberrations of wave surface not exceeding about $\frac{3}{4}$ wave-length for monochromatic light (wave-length 5461). It will be remembered that if aberrations do not exceed $\frac{1}{4}$ wave-length, the resolving power of an optical system is practically perfect. This was found by Rayleigh to be the case in certain cases calculated by him, and general experience shows it to be a sound rule.

The interferometer used for microscope lenses was a side issue in the development of other forms.*

An image of a monochromatic light source is thrown on a diaphragm which has a small hole. The light passes to a half-silvered mirror (Figure 1). A portion of the light is reflected from there to a concave mirror so situated that the diaphragm is approximately at its centre. From the concave mirror the rays are reflected, and a portion of the light passes through the half-silvered mirror, and is focussed on the eye of the observer. The light which, on meeting the half-silvered mirror passes through it, proceeds through a compensating plate as in the Michelson Interferometer; then through the objective under test. The rays pass on through the image, and are reflected back on their own path from a concave mirror. Eventually the two beams of light combine at the surface of the half-silvered mirror, and pass on together to the eye. In these circumstances interference effects are observed which appear to the observer as if located on the back lens of the objective under test, and which represent a contour map to a scale of half wave-lengths of the aberrations of wave surface produced by the objective under test.

If desired, an entire optical instrument, such as a microscope, can be tested, in which case the arrangement is as shown in Figure 2.

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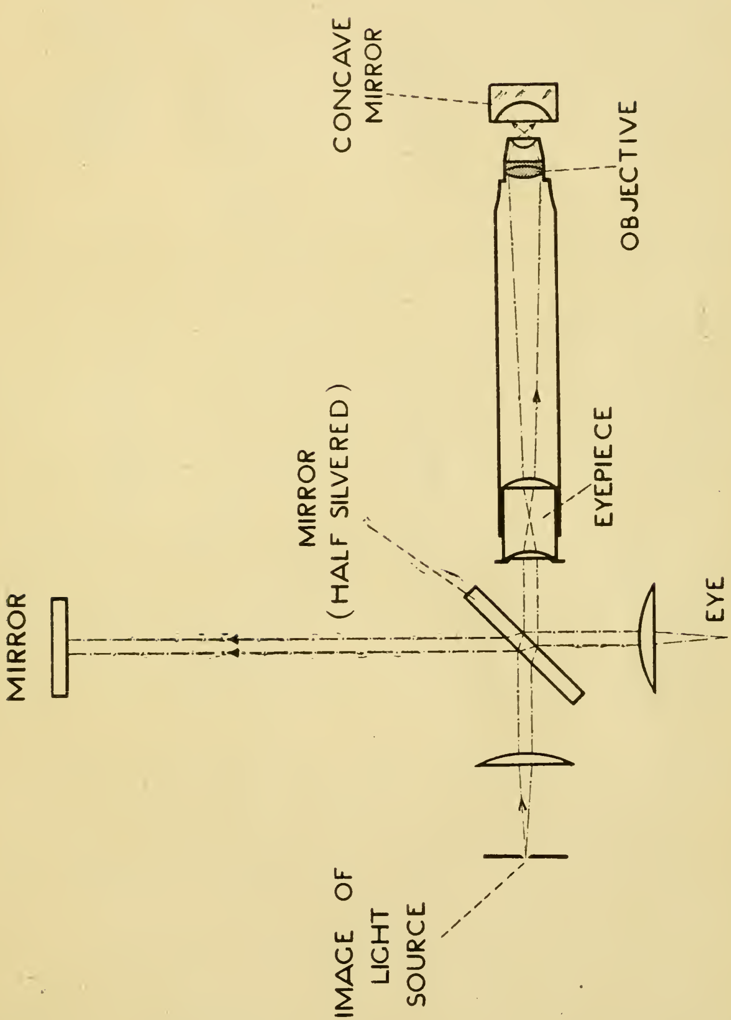
* Described by the present writer in the *Phil. Mag.*, Vol. XXXV., January, 1918, "Interferometers for the experimental study of optical systems from the point of view of the wave theory."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MIRROR
(HALF SILVERED)
CONCAVE
MIRROR
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EYEPIECE
EYE
IMAGE OF
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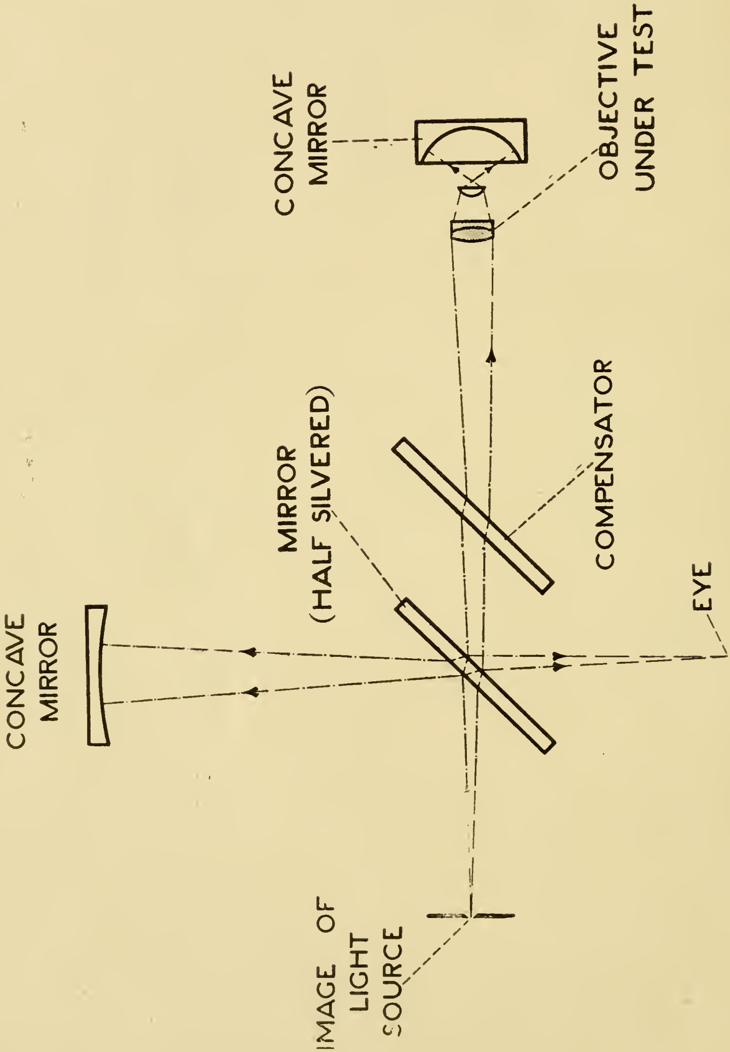
CONCAVE MIRROR
OBJECTIVE UNDER TEST
MIRROR (HALF SILVERED)
COMPENSATOR
EYE
CONCAVE MIRROR
IMAGE OF LIGHT SOURCE

AN ACCURATE METHOD OF OBJECTIVE AND SUBSTAGE CONDENSER TESTING.

By H. Hartridge, M.A., M.D.,

Fellow of King's College, Cambridge.

Preliminary Communication.

The methods of objective testing at present in use do not give quantitative data, and depend to a great degree on the keenness of vision, skill and memory of the observer.

A method which does not suffer from these defects consists in measuring with a suitable micrometer the position the image pattern when different parts of the objective aperture are used. If the lens is perfect and in correct focus no movement of the image pattern occurs. If there is movement, however, and if the micrometer reading be plotted against the N.A. of the part of the objective aperture in use, then the graph thus obtained shows the aberrations that are present and their amount.

A suitable method of isolating objective apertures of given N.A. was obtained by moving by means of a graduated micrometer screw a slit-shaped aperture placed below an oil immersion condenser. The method of calibrating the micrometer in terms of N.A. has been previously described.(1)

The best eye-piece magnification was found to be about 100 diameters; this was obtained by a 2-3 in. objective and a $\times 10$ eye-piece.

The glass plate micrometer proved most suitable for measuring the displacements of the image patterns.

The method of illumination has already been described.(2)

The typical graphs obtained for certain aberrations may now be briefly described.

Centre of Field.

Perfect lens (a) correct focus:—a straight vertical line; (b) incorrect focus:—a straight inclined line; (c) incorrect tube-length:—S-shaped line.

Imperfect lens (a) spherical aberration:—a sinuous line (not of regular S-shape), and never a straight line; (b) central astigmatism:—a different curve in one azimuth to that given by another.

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(1) Hartridge, Journ. Roy. Micro. Soc., 1918, p. 337.
(2) Hartridge, Journ. Quekett Micro. Soc., Nov. 1919.

Periphery of Field.

A straight vertical line indicates perfect lens in correct focus.

(b) An inclined straight line shows perfect lens in incorrect focus. If the inclination is different to that found at the centre, the difference shows the degree of curvature of field.

(c) A bent line denotes presence of aberrations:—disobedience of sine conditions, etc.

Experience shows that "performance curves" for the centre of the field show almost at a glance the aberrations present, and their degree. Interpretation of curves for the periphery of the field is more difficult.

Colour filters only have so far been used for obtaining approximately monochromatic light, a prismatic spectral illuminator would be a valuable addition.

It will be observed that this method of objective testing has been developed from the method of adjusting tube length described in a previous paper.(3)

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(3) Hartridge, Journ. Roy. Micro. Soc., 1919, p. 119.

REMARKS BY SIR HERBERT JACKSON, K.B.E., F.R.S.*

By the courtesy of the Chairman I was able to see in advance a great number of the interesting papers which have been prepared for this meeting to-day, and when I looked at them I discovered that practically everything that I intended to say was included in those papers. I have decided, therefore, that it would be better for me to be brief, and deal very generally with perhaps only two or three points.

I take it that one of the chief reasons for this Symposium is to consider methods for promoting the study of the microscope and methods for extending its use in science, in industries, and in education. I should like to mention first the position which we are in at the present day with regard to one of the most vital parts of the microscope, namely, the optical glass. I should like this meeting to know that through the enterprise of British manufacturers we have produced and we can produce optical glass in this country of a quality equal at least to the very best that was ever obtained from abroad. I should like also to say that I have had it from the manufacturers themselves that they are perfectly prepared to do their very best—and they have already shown that they can do it—to produce any glass which may be called for. There is a great deal yet to be done, not on their part so much, perhaps, as on the part of those whose duty it is to make investigations with the object of obtaining new glasses with optical constants differing from those which have been made hitherto, so that combinations can be made of even higher quality than those which we are familiar with in the best lenses that exist. I think also that it should be well known that, through the efforts of the Department of Scientific and Industrial Research and in other ways, mathematical investigation on methods of designing lenses are in progress, and I think we may look definitely from these investigations for results which will make a heavy demand again upon the skill and the enterprise of the manufacturers of optical instruments.

I will not speak, as I had intended to do, on some comparisons between the results of the work of British and foreign manufacturers, except to say that it is certainly true that we have produced optical trains in this country comparing favourably with any produced anywhere else, but we do not always produce them with that constant accuracy. I think it is fair to say that while, in the early history of the microscope we took the initiative, in later years there has been a tendency to follow rather than lead. At least, that is true of some of the chief developments of the instrumental part of the microscope. Now, what we have to do is no longer to copy, but to aim at improvements by independent research and invention. There exists at the present time. fostered by the Department which I have just mentioned, an all-round spirit of research and enterprise. Without elaborating the point, one can now express the hope that a bright promise of future development will not fail of fulfilment through lack of means on the one hand to attract the brains and skill which are abundant in this country, and on the other hand to

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* *See above, p. 43.*

make possible the large amount of experimental work which is needed and which of necessity cannot be made to pay except indirectly, and in the course of time. Unless we can get experiments of that kind made by the people in the factories, the hoped-for advances from the instrumental side will not be fulfilled, at least to the extent which some of us think and believe to be possible.

I turn for the moment to the point of view of education. The growing use of scientific instruments in industry definitely calls for some systematic education in the theory of them and in their practice. There has recently been created a School of Technical Optics under the Directorship of my friend Professor Cheshire. We may therefore look confidently to having opportunities afforded for a thorough and systematic education, now so much needed, in the subject of the microscope and its use. That need existed over 25 years ago, but I do not know that any marked efforts have been made to give the systematic education required. Take the difference between the subject of spectroscopy and microscopy. In spectroscopy the work of educating the student is carried out in a systematic way. There is lecture work and laboratory work, and I think the student of spectroscopy knows his instrument and his subject as well as it is possible to do in the time he is required to spend on it. It is difficult to believe that the student of microscopy ever had a chance of knowing his subject so systematically and thoroughly. Therefore I plead very strongly for the greatest possible support for Professor Cheshire, so that he may bring this question of education in the microscope to a really practical and successful issue. Of the many possible forms of propaganda, none is likely to have a better or more lasting influence in the direction of arousing interest in the subject and extending the use of the instrument. How many of us have seen people who begin with the microscope and abandon it very soon after taking to it, and in nearly all cases it has been due to this, that they have had nobody to show them how to use the instrument or to make them understand what the microscope is, what it is in theory and in practice, and they have often not been able to interpret what they see.

We have listened to an Address by Mr. Barnard which is very interesting to me, because I have had the opportunity of seeing his work, and I think he is to be congratulated on the scientific work he has done in extending the use of the microscope. But it is more than that. Mr. Barnard has that spirit of research and that spirit also of realising that there is to be interpreted in the microscope a great deal that has escaped observation, although it may have been seen dozens and even thousands of times. What I want to see is, in addition to the necessary lectures on the theory, the formation of classes in the use of the microscope where objects are studied at low powers and low numerical apertures, and at high powers and high numerical apertures, by transmitted light, on a black ground, and by opaque illumination; and each appearance critically examined and described.

There is a definite lesson as to how each type of image is to be interpreted. May I take one or two instances. If a well-known diatom, *pleurosigma angulatum*, is examined with an illuminating cone of not more than .3 to .4 N A , and with a lens like a 1 inch,

by ordinary transmitted light, what is seen is a brown or yellow-brown object. I am not going into the theory or the details, because it would take too long, and I am speaking to experts who, I am quite certain, know perhaps better than I, what is the explanation of the brown colour. But how many people who have looked at it simply as an object have asked "Why is it brown?" If you take that same object with a black ground illumination and a low angle objective, using an illuminating cone of .4 numerical aperture, all you see is the outline of the specimen. Yet what a wealth of information is to be gained from an investigation of the inside of that outline; Mr. Barnard has well indicated that when he was speaking of work in connection with the yeast cells. If you raise that cone to .65 with a black ground illumination, with the same objective, the object then is a beautiful blue or violet colour. Raise it still higher and it gets nearer to a greenish colour, and if you put on a little higher angle lens with an immersion condenser, the object looks very nearly white; raise the angle still a little higher and the image is white. That is an illustration of why every change should be explained and interpreted. Take another illustration: *tous-les-mois* starch grains mounted in water. With a black ground and an objective of a numerical aperture of .26, it is really a pretty object. The grains are nearly all pearly white, and the concentric rings can be seen quite well. If you keep the same objective, but raise the numerical aperture of the condenser, all the beautiful light goes, and nothing more than a mere outline can be seen; it looks like a little ring of light with nothing inside. Raise the aperture of the objective and use an immersion condenser, and you begin to see a little more showing up inside, and that is the first indication of the existence of a structure there. I should like the same thing to be taken with an opaque illuminator and examined. Opaque illumination, except in the examination of metals, has not had the attention paid to it that it should have because we have not laid sufficient stress on the necessity of looking at the object from all points of view, so as to decide by a careful comparison of the appearances in every possible form of illumination, the correct and proper interpretation. The student might be encouraged to go through a systematic course of theoretical and practical microscopy, applying what he learns in lectures to the study of objects of comparatively well-known structure by their examination with optical systems of increasing power and with various forms of illumination until he has gained a real knowledge of what can be revealed by the microscope and of what are its limitations. With this experience he would be in a position to proceed to research work equipped with sound theory and the fundamental practical knowledge necessary for the interpretation of what he sees and the avoidance of hasty judgment through incomplete observations.

If we could look forward to educational work somewhat on these lines in the future, people who wanted to study microscopy would find there was a great deal of valuable work to be done in extending the use of the instrument. The brilliant work which Mr. Barnard is doing in connection with ultra-violet light and increased resolving power cannot but help us very much in interpreting many things which we have seen but have not understood.

The following papers are extended descriptions of exhibits shown before the meeting.

NOTE ON LIGHT FILTERS FOR THE MICROSCOPE AND PHOTOMICROGRAPHY.

By LT.-COL. GIFFORD.

As far back as 1894 it was found that a solution of malachite green in glycerine absorbed all the visual spectrum except a broad band in the region of the F line of the solar spectrum, and a narrow red band near B (J.R.M.S., 1894, pp. 164-7), and that such a solution placed in a glass trough was eminently effectual as a light filter for microscopic use, especially when the red band was removed by inserting a piece of signal green glass into the fluid.

The year following, a screen similarly constructed, but with a solution of methyl violet for use in photomicrography, was described (J.R.M.S., 1895, pp. 145-7). In recent years it has been found that peacock-green glass possessed the same properties as signal green to a greater extent, and the use of the latter has therefore been dropped.

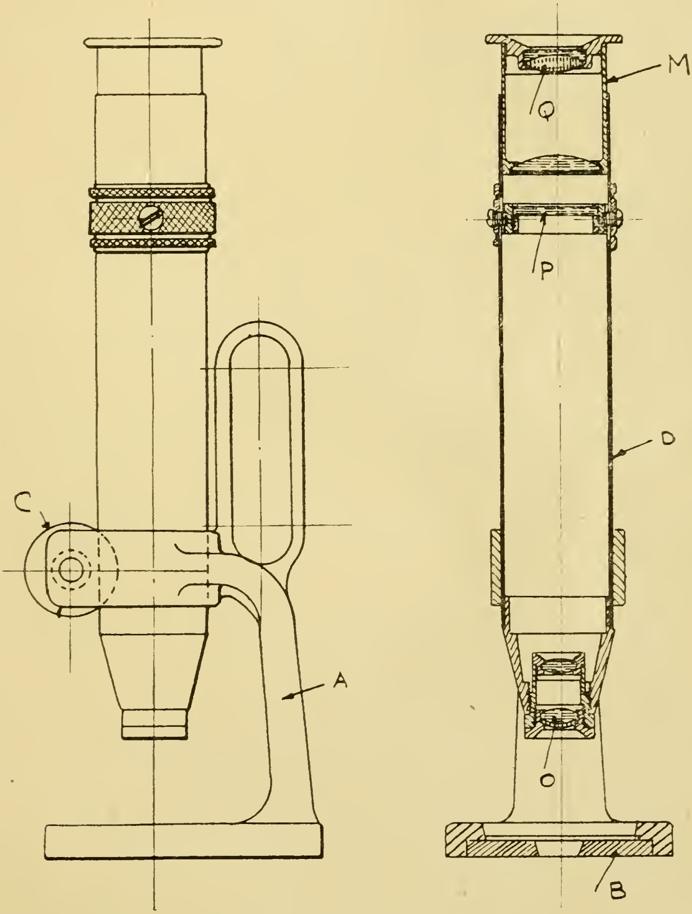
Instead of the glass trough with the signal green placed in it, the form these light filters have recently taken is as follows:—Discs of peacock-green glass about 0.06 in. thick and of diameter to fit into the substage condenser are cut out. On these discs are built up cells, using gold size and soft metal rings, or the former alone, just like those made for mounting microscopic objects in fluids. If a metal ring is used, then a coat of size must be given to the top of it and be allowed to dry. Then a final coat must be placed on that and allowed to get tacky. Then place rather more than sufficient dye solution in the cell near the edge. The glycerine will cause it to stand up beyond the top of the cell. Take a clean glass cover, make contact with the tacky gold size at a point nearest the drop of dye. The point of contact will act as a hinge. Now allow and assist the cover to fall until in contact with the gold size all round the ring. While the cover is falling and this contact is extending, the dye solution will flow forward and out in a wave. When contact is made with the top of the cell all round, take any blunt instrument and press the cover down in the middle until still more dye flows out. While this is being done adjust the cover on the ring if necessary, by the direction of the pressure. Quite a considerable pressure may be used, cover glasses are very flexible. When enough dye has passed out to leave the cover slightly concave, and you are assured that the adjustment is correct, suddenly remove the pressure. Pneumatic action will at once take place, owing to the resilience of the indented cover, and the edge of the latter will adhere so tightly to the gold-sized ring that it is possible to wash under the tap with a full stream of water at once. If made as described, the cell will not give out. Light filters made in this way are shown; one of them has been made and used for more than 20 years.

MICROSCOPE FOR MEASURING BRINELL IMPRESSIONS.

(Constructed by the Société d'Optique et de Mécanique de Haute Précision, Paris.)

The apparatus consists of two principal parts: the microscope properly speaking, and the limb or support.

The microscope itself comprises a mount D, carrying below an objective O, and above a micrometer P and an eye-piece Q. The objective is aplanatic and achromatic, and yields a linear magnification of 2.5. The micrometer has a length of 20 mm., which is divided



into 160 equal parts; numbers from 0 to 8 are marked every 20th division, so that a diameter of 8 mm. maximum can be measured within 1/20 mm. The positive eye-piece imparts to the whole system a total magnification of 21. The eye-piece rests in a small mounting M, which can glide in the tube D for adjusting the eye-piece with respect to the micrometer.

The support A consists of the foot, a mount, a split collar provided with a clamping screw and a handle. The microscope fits with gentle friction into the collar, so as to be definitely adjustable with respect to the impression to be measured; it is then fixed in that position by means of a screw C. In the base of the support is encased a disc of fibre B, which is provided with a central aperture through which the impression to be measured can be examined. This fibre washer, as shown in the annexed diagram and in the model, may be replaced by a washer of suitable shape, so as to be adaptable to the piece to be examined by the microscope. The microscope weighs 0.390 kg.; the mahogany case weighs 0.650 kg.

THE DAVON PATENT MICRO-TELESCOPE AND SUPER MICROSCOPE.

Exhibited by F. Davidson.

This apparatus combines in standardised and instantly interchangeable form the functions of the microscope, telescope, camera and projecting lantern for laboratory, educational and industrial purposes.

The principle employed is the utilisation of an " air " image of a more or less distant object projected to the plane of the microscope stage by means of lens attachments which are inserted into the " Abbe " rim of the microscope stand, and then using the microscope itself as an eye-piece.

Three different attachments are brought into requisition, viz. the long focus attachment, the short focus ditto, and a micro object glass forms the third. The first transforms the microscope into a telescope with a range of vision of from six feet to infinity, and magnifications of 20 to 50 diameters. The second is used for objects which, by reason of their size or shape, cannot be examined on the stage of the microscope, such as minerals, metal fractures, etc., the visual range being from three feet to one foot from the stage of the microscope and magnification from 30 to 90 diameters. The third in combination with the microscope itself forms the super microscope. Magnifications of from 75 to 150 diameters with working distances of from four to two inches or of 1,500 diameters with working distance of $\frac{1}{4}$ in. are characteristic features.

Either attachment may be used for photography. With the first, photographs have been taken at distances of 6 feet and 70 miles, with the same combination; with the second, insects at from 18 ins. to 24 ins.; and with the third attachment, photomicrography of a wide variety of subjects at various magnifications from 1 to 3,000 diameters with excellent results.

The outstanding feature of all views and all photographs is the very great " depth of focus." This is so good that everything is shown in apparent stereoscopic relief.

The principle of photography with either attachment is the same, and consists of substituting a camera for the body tube of the microscope and virtually using a microscope objective as the eye-piece. No long extension camera is therefore necessary, exposures are shortened and vibration minimised in high power photomicrography. Photographs of Himalayan Peaks 60 miles away, and blood corpuscles at a magnification of 3,250 diameters have been taken in a $\frac{1}{4}$ plate without more than the ordinary extension.

The illuminant is arranged in an optical lantern with a 4 in. condenser and a supplemental condenser in a mount which fits the " Abbe " rim of the microscope. For projecting light on to a more or less distant object the 4 in. condenser is used alone. For photomicrography the supplemental condenser only is used, while with the two in combination effective micro-projection may be done without any accessories.

It is impossible in a briefly outlined description of the apparatus to indicate the wide variety of uses to which the apparatus lends itself, and it is no exaggeration to say that a new and wider field of observation and utility is opened up in many directions.

DISCUSSION AT SHEFFIELD.

Tuesday, February 24th, 1920.

At a meeting of the Sheffield Association of Metallurgists and Metallurgical Chemists held at the Royal Victoria Hotel, Sheffield, on Tuesday, February 24th, 1920, further discussion took place on those papers presented at the Symposium at London, on January 14th, which dealt with the use of the microscope in Metallurgy and Metallography.

The meeting was held in co-operation with the Faraday Society and it was attended by members of other local bodies and by the members of the local sections of the Institute of Metals and the Society of Chemical Industry.

Mr. J. H. S. Dickenson, President of the Sheffield Association of Metallurgists and Metallurgical Chemists, was in the chair and he presided over a large audience.

The CHAIRMAN, having explained the objects of the meeting, called upon **Dr. F. C. Thompson, Mr. T. G. Elliot, Mr. J. H. G. Monypenny** and **Mr. F. Atkinson** to introduce briefly the papers they had contributed to the Symposium in London. Other papers were distributed in proof form.

DR. THOMPSON'S paper was entitled "The High Power Photomicrography of Metals."

SIR ROBERT HADFIELD and MR. T. G. ELLIOT'S paper was on "Photomicrographs of Steel and Iron Sections at High Magnification."

MR. J. H. G. MONYPENNY'S paper was entitled "Some Notes on the Metallurgical Photomicroscope."

The paper by MR. LESLIE AITCHISON and MR. F. ATKINSON was entitled "Metallurgical Microscopes and their Development."

DISCUSSION.

Dr. W. H. Hatfield did not think that there was any point on which he joined serious issue with the authors of the papers read that evening. Mr. Monypenny said that many people used the microscope and did not properly understand it. That was so. But looking at it from another point of view, there were people who regarded the microscope as a tool and looked to the manufacturers and the optician to further extend its usefulness. That was his position, and, generally speaking, the position most metallurgical investigators would take up. From that point of view one could tell the people who were making a speciality of the microscope what the metallurgist wanted. We might first of all tell them what we could do. From his own metallurgical experience he could obtain delightful microphotographs under ordinary conditions, and with ten magnifications get excellent empirical microphotographs. This was also the case with 50, 100, and up to 1,000 magnifications—excellent, almost perfect definition could be obtained. Beyond 1,000 diameters, however, we could not do so, and that was an essential thing to put before the people who were out to assist us in the use of the microscope.

There were a whole series of problems awaiting adequate solution, including the recrystallisation of cold-worked material, and solutions could only come when we have better facilities for definite and accurate information as to the internal architecture of the material at magnifications well above a thousand. We had produced very pretty photomicrographs up to three thousand diameters—Sir Robert Hadfield has produced excellent ones up to eight thousand—but these magnifications did not give us much more information than we could obtain by a clear definite picture at a thousand. If the Symposium had brought those facts before the notice of manufacturers of the microscope, it would have served a great purpose to metallurgists.

Dr. F. Rogers thought that the theory of lens design had been evolved much further than the theoretical side of metallurgy itself, heretical as that might seem. In reference to the high magnification work done by Sir Robert Hadfield and Mr. Elliot, he emphasised that whilst magnifications of 8 to 10 thousand were interesting as pictures, they did not contain any more detail; they were, in fact, of no greater value than enlargements. Nevertheless, he welcomed this high magnification as a progressive step, even though the result as regards detail was a negative one.

He put in a plea to metallurgists that they should make their photomicrographs bigger; if they were, an advantage would be gained. Such enlargements were better understood by the non-expert, even if perhaps as a record they were not so good. In regard to fine structures in the alloy steels—especially, for instance, in the study of temper brittleness—he would welcome anything which would give further resolution of detail. This information, he felt, was hidden away from them just at the limit of what the microscope could do. He thought the microscope would ultimately contribute to the solution of that problem.

Mr. J. N. Greenwood referred to the difficulty of discussing the many points at issue. First of all there was the perfecting of the design of the optical system of the microscope itself. That was definitely a question to be tackled by the opticians. On the other hand there was the question of the use of the microscope, and in that connection there were very great improvements necessary in a good many cases. As regards the question of vibration, one speaker suggested that the people who supply the microscopes should supply some means of getting over this trouble. But the trouble could only be rectified by each user of the microscope himself, because at the various laboratories where the microscope was found the component vibrations were different. Sometimes it was the vertical which preponderated and sometimes the horizontal, and the question of the situation and the type of machinery close by had to be gone into before the vibration should be overcome.

As regards magnification, a good many metallurgists were expecting more from the microscope than was likely to be forthcoming in the near future. As far as he could see, unless there were some absolutely new development in the way of objectives we were not likely to get anything approaching the increase of magnification and resolving power which some metallurgists desired. Magnifications of 1,500 were now quite possible, and every one obtained them more or less easily. But to get at the bottom of such problems as brittleness and cold working we should have to get far beyond what we had been doing and approach molecular dimensions; even at ten thousand we were still a very long way from seeing molecules. It seemed to him that something like 100,000 would be nearer the mark, and he could not see how from the present system and using reflected light that we were likely to get anything of that order. If the opticians gave us 10,000, then they would have reached their limits with the present methods. He thought there was more prospect of getting information by examining other physical properties apart from or in conjunction with the microscope. He concluded by saying that during the past five weeks he had given more time and study to the microscope than he had during the last five years, so that in fixing attention on points like this, such discussions are invaluable, because few people had time to gather information of this kind.

Note added March 6th.—It has been suggested that I am pessimistic with regard to possibilities of higher magnification. I do not wish to convey the idea that I do not look for any improvement in magnification, but rather than in the two problems mentioned the probable improvements in the microscope will scarcely go far enough. On the other hand, there is an enormous field of utility for magnifications (with correspondingly high resolving power) of the order of 5,000, in defining the structures of special steels.

Mr. G. R. Bolsover said the papers resolved themselves into three types. A certain section dealt with the historical side, another with the utility of the microscope, and the third with the microscope as an instrument. The historical side was dealt with mainly by Sir Robert Hadfield in two papers. He suggested that in

dealing with the work of Sorby that account could with advantage be extended to include not only the work of Sorby, but his life as well. In the case of a man who had done so much for science and incidentally for civilisation as a whole, we should have a permanent record of this man's birth, training, and career in detail up to his death, apart from the question of his work.

As regards the microscope as an instrument, he agreed that it was the optician's affair. There were many comments in the papers on the different forms of microscopes. His experience had been that there were many microscopes on the market capable of giving excellent results when properly used, but they were not made to meet the particular fads of individual workers. Results were dependent more on the individual than upon the particular type used. There was in use in his laboratory four different microscopes—one Austrian, one French, one modern, and one ancient British. It was possible to get good results from all of these. The two oldest were the Austrian and the old British. The latter was perfect in almost every respect, whilst the stage of the Austrian could be moved through quite a considerable angle in the direction in which it should be perfectly rigid. He did not think they need fear much from the superiority of the Austiian make of microscope.

With regard to stages, he uttered a word of warning—do not get a levelling stage. It was a distinct advantage to have an up-and-down movement of the stage in order to avoid altering the light sources for sections of varying thickness. On the question of light there were a number of elaborate schemes for lighting for visual work, but they got excellent results with the ordinary electric bulb with the interposition of a ground glass screen. One could get a light sufficient to show all detail, and it did not tire one's eyes. As to the source of light for photographic work, he was rather interested in some of the papers in which it was suggested that the arc was too uncertain a source and suffered from flickering. They had tried both the arc and the "Pointolite," but preferred the arc, and got excellent results from it.

Mr. Atkinson pointed out that the focussing arrangement for long distance work was one that required a great deal of attention. At times a considerable extension of bellows is required to take a photograph, and unless a really good apparatus for focussing was available, it was very difficult to get a fine adjustment.

With regard to higher magnification, one direction in which he anticipated this would be an advantage was in the disproving of certain theories at present in vogue with regard to crystallisation, but there was still a tremendous field to be explored with the facilities which were now available. Another difficulty with regard to higher magnifications was the question of polishing and etching. With the present method of polishing it was practically impossible to get a plain surface to examine, and when one came to etch the difficulties were increased. The difficulties were really enormous, and until they were removed there would be great difficulty in examining steels, let alone photographing them at high magnification.

The Chairman: Dr. Thompson refers to the Reichert microscope, and says very good results can be obtained when the disc illuminator is used instead of the pair of prisms ordinarily fitted. Does he know whether such a microscope has been made by Reichert?

Dr. F. C. Thompson: Benedicks has adapted one himself for that purpose

The Chairman: Another point is with regard to vibration, and regarding this I would point out that Dr. Rogers would not use a four-metres extension if his apparatus was established near a steam hammer. Usually in a works it is necessary to use a short extension for this reason.

Dr. F. Rogers: There is a good deal in that. I am glad that the discussion is touching on the question of vibration. It has been suggested to me that the whole apparatus should be afloat on water or oil. It seems to me a rather good idea, but I don't suggest that you should have to swim to it. I have not worked out the detail, but I think the problem will be ultimately solved in that way, perhaps combined with springs or india-rubber moorings.

Dr. W. H. Hatfield: Arising out of this discussion there is one thing I should like to say with regard to my experience. I have done a great deal of photomicrography, and for one period of something like six or seven years I used a Watson microscope. Now, that microscope cost about 50 to 55 guineas, whereas the Zeiss cost about 100 guineas. I produced well-nigh perfect pictures at 1,000 and slightly over. In fact, the work was equal to that given by the Zeiss, and I shall be glad to show anyone the slides. I mention this because so much has been said about the German manufactured article being better than the British, and I think it is only fair that we should put that on record.

Mr. L. Dufty drew attention to the different magnifications given in the various papers, and suggested that it would be a great improvement if standard magnifications were adopted. Another thing that should be stated in the papers was what objectives and eye-pieces were used. It would be a great advantage if these were given when stating the magnifications.

The Chairman: The matter of standard magnifications is mentioned in Sir Robert Hadfield's Introductory Address. The American Society for Testing Materials has issued a list of standard magnifications which, as far as my recollection goes, runs in fifties. It is open to every investigator to work to simple, round figure, magnifications.

Mr. L. Dufty: Yes, but you will see investigators often work in anything except round figures.

The Chairman: I am sometimes ashamed of some which I see hanging in my laboratory which are marked " ×117.5," but these were taken 18 years ago, and we have now for many years worked to a few fixed round-figure magnifications.

Dr. T. Baker: Those of us who have had the opportunity of examining the work of old masters in the art of photomicrography I think will agree that they, with imperfect apparatus, turned out much more satisfactory work than many of us to-day do with a much more perfect equipment. A great deal depends on the operator, and a closer study of the construction of the microscope would assist him in avoiding the pitfalls into which a good many metallurgical microscopists are apt to fall. There is a great tendency to make the metallurgical microscope too complex; amongst the fittings to be avoided are levelling stages and centering nose-pieces; a centering stage is much better than the latter, since it can be much more substantially constructed.

As regards objectives, apochromats are without doubt a valuable asset to the skilled worker, but how many can distinguish between the image formed by a good achromatic and that given by an apochromatic objective, without the assistance of the inscription on the mount; then, again, by far the greater part of the work of a laboratory does not call for the use of apochromats.

As regards magnification, it is generally stated in the standard works on the subject that little if anything is gained by using magnifications greater than 1,000 times the numerical aperture of the objective, so that until the resolving powers of objectives are increased there seems to be little advantage in pushing magnifications much beyond 1,500 diameters.

As an illuminant the speaker prefers the direct current arc to the " Pointolite " lamp, in spite of the fact that the latter has several points in its favour, such as steadiness and constancy of brilliancy. The prism form of vertical illuminator appears to have fallen into bad repute; the speaker, however, prefers it to the cover-glass type, in spite of the fact that it reduces the numerical aperture of the object by one-half in one direction, a weakness which is not such a serious matter as many try to make out.

Mr. H. Wrighton said he had considerably reduced the flare in a 4 mm. .95 N.A. objective by blacking the inside of the mounts near the front of the objective, which were brightly polished. He produced further photographs of a very fine pearlitic structure, and said he considered that, taken at 8,000 magnifications, was better than the corresponding photograph of the same field at ×1,500, as the details of the structure could be more plainly seen. A Zeiss × 12 compensating eye-piece was used in obtaining the photographs at 8,000 magnifications. He submitted photographs of a long distance fine focussing adjustment he had fitted to his Zeiss-Martens horizontal microscope, and found to be quite satisfactory.

Mr. J. H. G. Monypenny, referring to the capabilities of different stands, said he had never met one to equal the large " Works " model made by Watson. He had used one of these stands fifteen years, and it was still in perfect condition. He had tried a number

of other stands, including the Zeiss-Martens, but had not seen one to equal the Watson. Opinions differed as to the relative wearing qualities of British and German stands; there was no doubt, however, that the better quality British stands were good instruments, and would stand a great amount of use; at the same time they could be improved by using more suitable kinds of metal for the moving parts, such as pinions and racks.

With regard to objectives, the English achromatic lenses worked perfectly, providing they were used with yellow-green light, and with low and medium powers one could obtain results comparable with those given by Zeiss apochromats. For low power work they had the advantage of possessing a much flatter field than the apochromats, but they did not work well with blue-violet light. Some of the new apochromats made by Watson and Swift were, he believed, very good lenses, but he had not tried them. For the highest powers the apochromat was much superior to the achromat, though good results could be obtained with the latter.

Several remarks were made about fine focussing arrangements. Nearly all his work had been done with a vertical camera, and, being endowed with a rather long arm, he had not needed any extended arrangement for focussing. The arrangements he had seen have been rather a nuisance, and probably the worst was the one fitted to the Zeiss-Martens stand.

For very low power work he did not think any ordinary type of microscopic objective suitable if one required a large field. Some type similar to the Zeiss projection lens was much better; with such a lens one could easily obtain a field up to ⅝ in. diameter.

With regard to the use of prism or disc illuminators, in spite of what had been said, he believed the disc was very much better than the prism for high power work. Providing the structure was suitable and the detail in the section arranged in the right direction (that is, with respect to the prism), one could obtain very good photographs with the prism illuminator, but in most specimens, for example, of pearlite, the laminae were arranged at different angles in various part of the field, and it was impossible to arrange it so that each set of laminae was in the best position to be resolved. For low power work there was no doubt that the prism was superior to many individual discs on the market for the reasons given in his paper.

Reference was made in one of the papers to the impossibility of obtaining good contrast with medium power dry objectives, such as the 1/6th inch, owing to flare due to reflection of the incident light at the front surface of the objective. He had used a Zeiss 4 mm. apochromat for some years for metallurgical work, and found it quite easy to obtain sufficient contrast. It would be very inconvenient to have to use an immersion lens for such powers.

Several references had been made during the discussion to the various types of metallurgical stands. Many of the new fancy stands were no improvement on the old type, and very often they were much worse. In a metallurgical stand, the stage should have a coarse adjustment, but the fine adjustment should be on the tube. In any case, the milled head for the fine adjustment should not be fixed to a movable part of the stand (such as the stage), as, if so,

the flexure due to the pressure of the hand might be sufficient to affect the focus of a high power objective. In this respect it might be mentioned that when using a 2 mm. immersion objective of N.A. 1.40 a movement of $\frac{1}{50,000}$ of an inch along the optical axis was sufficient to put the field out of focus.

With regard to Dr. Thompson's remarks on the halo produced round the fine detail in photographs at very high magnifications, while agreeing that such halos were produced, he thought their width was rather less than stated by Dr. Thompson.

Mr. Birch pointed out that by the use of different screens photographs were obtained which seemed to represent two totally different things. The whole process of photography should be understood besides the optical system.

Dr. W. H. Hatfield said that with regard to the standardisation of magnifications in his laboratory, they had found it helpful to standardise to 10, 50, 100, 500, and 1,000 diameters. It would be very helpful in studying the work of other people if the photographs were of the same magnifications.

Mr. J. N. Greenwood: The question of the size of reproduction also arises.

Dr. W. H. Hatfield: I suggest that the matter is worthy of consideration.

The Chairman: Such standards have been laid down in America.

Mr. T. G. Elliot: Sir Robert Hadfield has taken a great interest in the question of standard magnifications for photomicrographs, and he long ago decided to use standard magnifications in his own research laboratory. He took a practical interest in the work of the Committee of the "American Society for Testing Materials," which was responsible for drawing up the report on "Magnification Scales for Micrographs," which has already been mentioned this evening, and several of his suggestions were adopted and are included in the revised report, published in June, 1918. In that year, too, Sir Robert endeavoured to get the British Engineering Standards Committee to take up the subject in this country. After due consideration, however, they decided against it, because they felt it would be impossible, at that time, to standardise the lenses to be used in obtaining the magnifications, without which the standardisation of magnifications would be useless. It was also thought that this matter and the related one of the full-sized reproduction of photomicrographs might well be left to the Publications Committees of the various Societies interested.

The Chairman said that in his laboratory they had adopted 100, 250, and 750 as standard magnifications.

Dr. F. Rogers advocated the adoption of round-number standard magnifications for reproduction and report purposes.

Dr. F. C. Thompson said it was at times very difficult to confine oneself to given magnifications. The Institute of Metals had brought out a list of magnifications seven or eight years ago, and authors of papers were requested to confine themselves to those standards, but no attempt appears to have been made by the Publication Committee to enforce these, and he did not think they were being observed now.

With regard to stands, in his experience the English stand was absolutely unsurpassed. They had some very old Beck stands at the University which had been subjected to extremely hard work, and even now those stands were in excellent condition. The same applied to geological and other stands by Watson's, which were being subjected to equally hard work. They appeared to be a distinct improvement on anything that foreign countries could supply.

With regard to objectives, the position was not quite the same. For lower power English objectives were most admirable, but he agreed with Mr. Monypenny that above one-sixth the Zeiss was much better. Dealing with illumination, the arc lamp, if it was working well, did quite admirably. Small arcs, however, were very unsatisfactory. If it were not for the increased amount of attention required, the ideal illuminant was the lime light. One got large area of illumination of high actinic value if one took the necessary trouble.

A Member remarked that if a standard for magnifications was fixed there should also be a standard of objectives for each magnification.

The Chairman: On this matter of standard magnification this Association might very well have the views of all our members using microscopes ascertained and a memorandum prepared.

Mr. F. S. Spiers said that an important factor in determining the size of reproductions was that of cost. Anyhow, that placed an added difficulty in the way of standardisation. With the permission of the meeting he would like to bring up the subject before the Council of the Faraday Society, and perhaps some steps might be taken in the direction of standardisation. There were one or two things mentioned in the discussion in London which he thought it of interest to bring forward, notably the suggestion to form a standing committee to undertake proper tests of objectives now being manufactured. It was hoped that would settle once and for all the question of the merit of British objectives.

The Chairman: It appears that members of our Association are not quite unanimous on certain points. In the first place, as regards the question of disc *versus* prism illumination. I may have been unfortunate in my experience of prisms, but I always find that I can get better photographs with even ordinary covered glasses than from any prism, and, judging not only by my own results, but by those of my friends, I must say the glass disc illuminator is much to be preferred to the prism. The other point on which there is a sharp difference of opinion is with regard to illuminants. I have

found the "Pointolite" extremely useful and, if properly used, it gives excellent results. It gives a very steady and strong illumination, and may be used for everything except screen projection, when the greater power of the arc lamp is required.

I think rather too much has been said to-night with regard to photomicrography, and too little about the use of the microscope for purposes of examination and study, especially at high powers. Actual research work is not done by examining photomicrographs, but by prolonged visual inspection of structures under the microscope. It is rather the tendency nowadays to take a photograph and hardly look at the specimen at all; but, after all, photographs are only imperfect illustrations necessary for reports and publications.

As regards the present indifferent construction of microscopes, I consider that it is for the metallurgical engineer, who should know what he really requires, to design the mechanical details of his microscope, leaving the optician only to deal with the optical system. Further, with regard to existing microscopes, I quite agree that English microscopes have been very unfairly condemned in comparison with Continental instruments, although as regards objectives English makers do not seem to be able to keep up to the same standard of excellence as Continental makers, but they occasionally turn out lenses which are as good as can be obtained anywhere. Then, as regards enlarged photomicrographs, I must say that I fail to see any point in enormously high magnifications obtained by this means. Such photomicrographs at, say, 5,000 diameters magnification, give no information which cannot be obtained from a photomicrograph at 1,000 diameters.

Dr. F. Rogers: As an enlarged photograph it is of some use.

The Chairman: Yes, as a picture for hanging on a wall. You can, of course, go up to enormous enlargements by the use of a lantern, but this only assists by permitting more people to see the photograph at one time.

Mr. T. G. Elliot: A photograph taken at 5,000 magnifications has this advantage over an enlargement, that before taking the photograph, you select your field at this magnification, and, as we say on page 5 of our paper, "we consider this an important point." We quite agree with Mr. Dickenson and other speakers who have criticised the use of very high magnifications, that nothing new has been learnt from them; although we submit that inasmuch as they do enable one to see the details of the structure easier, they have this important advantage over photographs taken at lower magnification. It was partly because Sir Robert Hadfield believed that we had got as far as was practicable with the apparatus available, that he suggested a Symposium on the Microscope, in the hope that it would focus attention on this point and lead to increased effort to obtain apparatus which would open up new fields of investigation.

Dr. F. C. Thompson, replying to the discussion, said that as the wave-length of light decreased the resolving power was increased. Up to the present ultra violet light had been unsatisfactory with metallurgical specimens, though there was no obvious reason why

this should be so. With regard to Mr. Monypenny's criticism of the diameter of the halos, he had formed his conclusions on the ordinary laws of optics, and there was no very obvious reason for departing from it.

Mr. J. H. G. Monypenny said he was quite in accord with what had been said with regard to magnification, that the limit is reached at 1,500 diameters. The only advantage in photographing above 1,500 (apart from photographs for reproduction purposes—in which case enlargement is sometimes desirable), might be in the case of a man whose vision was not as good as it might be, or who did not wish to tire his eyes examining every detail.

The Chairman, in concluding the meeting, said: We are very glad to have had the opportunity of discussing in Sheffield the papers on microscopy which were recently read before the associated Societies in London, and I think I may say that this Association is grateful to Sir Robert Hadfield for making the suggestion that such a further discussion should take place. If, and when, the Faraday Society has another Symposium on some other subject, this Association will, I am sure, be pleased to arrange for another joint local meeting on the lines of that held to-night.

ADJOURNED DISCUSSION IN LONDON.

April 21st, 1920.

The Royal Microscopical Society held a special meeting on April 21st, 1920, in the Rooms of the Society at 20, Hanover Square, London, W., in conjunction with the Optical Society and the Faraday Society, to discuss the papers presented to the Symposium which dealt with the "MECHANICAL DESIGN AND OPTICS OF THE MICROSCOPE."

Professor John Eyre, President of the Royal Microscopical Society, who was in the Chair during the first part of the proceedings, opened the Discussion with the following remarks :—

The object of our meeting this evening is not to initiate a fresh discussion on the microscope, but to continue the work which was commenced at the Symposium held in January last. The volume of communications which was simply poured upon the Symposium was so great that it was impossible to discuss more than a very few of them, and, indeed, many papers were only presented in abstract, but in order to correlate the views of all the workers in this branch of science, we are arranging a series of short meetings in which specially selected papers can be discussed, and the results of the discussion recorded for publication. During the course of the evening my two confreres, Sir Robert Hadfield, President of the Faraday Society, and Mr. R. S. Whipple, President of the Optical Society, will each take the Chair for a period, in order that the members of their Societies may feel that they are adequately represented.

The Chairman then called upon **Mr. J. E. Barnard** to give a GENERAL SURVEY of the subject (*see* page 37), after which abstracts of the following papers, read at the original meeting, were presented by their respective authors:

THE MECHANICAL DESIGN OF THE MICROSCOPE.

(*a*) *General.*

PROFESSOR F. J. CHESHIRE, C.B.E., "The Mechanical Design of Microscopes."

MR. CONRAD BECK, C.B.E., "The Standard Microscope."

MR. F. W. WATSON BAKER, "Progress in Microscopy from a Manufacturer's Point of View."

MR. POWELL SWIFT, "A New Research Microscope."

(*b*) *Metallurgical.*

Dr. W. Rosenhain, F.R.S., "The Metallurgical Microscope."

Professor Cecil H. Desch, D.Sc., "The Construction and Design of Metallurgical Microscopes."

Mr. E. F. Law, "The Microscope in Metallurgical Research."

Mr. H. M. Sayers, "Illumination in Micro-metallography."

(*c*) *Petrological.*

Dr. J. W. Evans, F.R.S., "The Requirements of a Petrological Microscope."

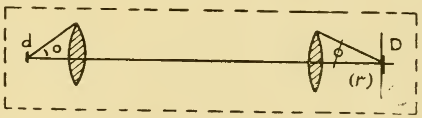
Sir Robert Hadfield, F.R.S., in taking the Chair during the reading of the metallurgical papers, said:

I do not intend to take up much of your time, but should like to say in a few words how very gratified I feel to see this important gathering continuing the work we tried to do a couple of months ago. We then had something like 40 papers presented, and as, of course, it was quite impossible to do more than touch upon the fringe of the discussion of them, I may also add that out of that large gathering in the Rooms of the Royal Society we have had a continuation of the same work in the cities of Sheffield and Glasgow. That will show you that we did really stir up not only the metropolis, but also the north and the far north. As I am taking the Chair during the reading of the papers in the metallurgical section, I would like to say how very important we find the microscope as regards metallurgical operations and investigations. My friend Mr. Barnard has said that we do not think sufficiently of resolution and that we are rather too fond of magnification. I still have a little feeling for magnification, but cannot help thinking that we shall, aided by resolution—the double resolution of the microscope and our own resolution—find out improved methods of handling steel. That is a matter I am specially interested in. The more one studies the structure of iron and steel, the more fascinating it becomes. To use an illustration in which I have been concerned very much during the war, *i.e.*, the production of the large calibre armour piercing shell, we could not really have obtained a shell of the requisite quality without the use of the microscope. When one considers that the 18-inch gun carried a projectile with a muzzle energy of 150,000 foot-tons, one can imagine the tremendous stresses which occur when that shell is suddenly brought to rest by the armour attacked, and yet it must not break. Out of those war researches are proceeding further investigations which will apply that information to the arts of peace, and I do not think it will be found that we have wasted our time. We in England were not behind, but we wanted stimulating a little, and a great deal of investigation work was carried out during the war which would not have been done otherwise, because in times of peace the money could not be found.

Discussion.

Commander M. A. Ainslie, R.N.: With regard to design, the principle of the optical bench seems to me exactly the principle needed in order that you may build up in bits the apparatus you want for any particular research, so that everything may fall naturally into alignment. Each piece of apparatus should be on a separate saddle of its own. I would even have the eye-piece on a separate saddle, with a separate coarse adjustment of its own; this may sound revolutionary, but I believe it to be perfectly sound. Then, again, I think we ought to have a longer range to the draw-tube; as a rule, it is quite insufficient, especially when high power dry objectives are in use. An ordinary dry 3 mm. objective requires a change of about 20 mm. in the tube-length to compensate for a change of .01 mm. in the thickness of the cover glass; and although objectives of lower power are less sensitive, objectives of low power and large aperture are not very easy to obtain.

With regard to the size of illuminant required in photomicrography, whether of metals or of other objects, this is settled by a very simple relation. If d be the diameter of the light-source, and D that of the illuminated area on the object slide, and if θ be the



angle made with the axis of the extreme ray entering the optical system and ϕ that of the extreme ray falling on the object, the latter being supposed in a medium of refractive index μ, then we always have

$$d \sin \theta = \mu D \sin \phi,$$

which is, of course, merely the well-known "optical sine law"; it really amounts to saying that the product of the diameter of the light-source into the N.A. of the collecting lens is equal to the diameter of the circle of illumination on the object, multiplied by the N.A. of the condenser. You cannot get away from this relation; it settles once for all the diameter of the illuminated field, and it is true for any optical system whatever between the light-source and the condenser.

If you are going to use a metal filament lamp, you are confronted with one of two things; either you are going to project an image of the filament on your object, or else you are going to project this image into the plane of the objective aperture, filling it irregularly; a state of things which Professor Conrady long ago showed to be incorrect. The diameter of the filament is far too small, having regard to the relation I mentioned just now; and of course one does not want an image of the filament on the photograph.

With regard to the intensity of the arc, what decides the exposure is the intrinsic brilliancy and not the total power of the arc. As to the heating effect, I have used a 25 ampere arc within

$1\frac{1}{4}$ inch of one of the solid glass rods supplied by Messrs. Beck, for half an hour at a time, without the slightest damage to the glass, and I am inclined to think that this " bogey " of the danger to your collecting lens is somewhat over-rated.

Mr. C. Beck: Has Commander Ainslie tested the amount of light lost by absorption from glass to glass. Is it 75 per cent.?

Commander Ainslie: Yes, of course, a great deal of light is lost. It was a question of the capability of the glass to withstand heat. It is a question of the size of the illuminant. I have seen a piece of ground glass as the source of illumination instead of the crater of the arc itself.

Mr. Maurice Blood: You can use a large collecting lens.

Commander Ainslie: But you will not get more light, because it is the intrinsic brilliancy of the light that counts.

Dr. R. Clay: The feature that pleases me most in the microscopes that Mr. Beck has shown is the provision that he has made by which one can start with a simple form and gradually build it up. I have been advocating this for some time, and I am very glad to see it is accomplished here. That a student who has not too much money can commence with an inexpensive instrument and add to it as he goes along, and as he feels the necessity for and understands the use of improved apparatus, is a very great advantage.

I was very much interested in Commander Ainslie's formula connecting the area illuminated by a substage condenser and the aperture of the condenser. I think it is one of the most important things that has been brought forward during this Symposium, because there is quite a lot of nonsense talked about the illumination of microscope objects, and that formula puts the whole in a nutshell. I was also interested in the paper on the illumination of metallurgical specimens, as I think it is possible with a prism that I devised some time ago for another purpose to give the 50 per cent. illumination that has been asked for in that paper.

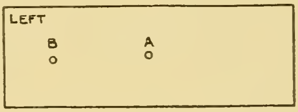
Mr. W. R. Traviss: I should like to mention that it is over 35 years ago since I introduced to Messrs. Swift and Son a microscope on the lines of the one that the last speaker has said he would like to see, viz., an instrument that could be commenced in a small way and gradually built up as time goes on.

The simplest form had a firm tripod, of which the toes of the legs were cork-filled to give firmness. The stage was a cut-open form recommended by the late Dr. Dallinger and Mr. E. M. Nelson. The coarse adjustment was made by the body sliding in a cloth lined fitting. The screwed holes for the attachment of the limb or arm to the stage were made a standard distance from the optical centre, so that a coarse adjustment with rack and pinion movement could be exchanged. The side edges of the stage were grooved for the vertical movement of a mechanical stage or roller sliding bar which

could be easily slipped on and off. The under-stage tube was fixed to a plate; this could be replaced by a centering motion, rack and pinion sub-stage. The sliding draw-tube could be replaced with a rack and pinion draw-tube divided into mm.

Another addition which is added to a small portable microscope, and would be useful to all plain stage microscopes, whoever the maker might be, is a very simple and efficient finder, and is standardised as follows:—

Each maker has a 3 × 1 in. piece of metal 1 mm. thick. At equal distances from the ends and sides is made a small hole (A) 1 mm. diameter, and another hole the same size, made exactly 1 in. distance from the centre hole and equal distance from the sides (B), thus:—



When an instrument is assembled and completed ready for sale the above plate is placed on the stage of the microscope resting against the sliding bar or mechanical stage, or a mechanical square; then with a 2/3rd or 1 in. objective the hole A. is brought into the centre of the field of the eye-piece; the metal 3 × 1 is held firmly by the stage springs or clips, and a small sharp drill is passed through the hole B and a few twists given, which will make a drill mark on the stage. This is then filled in with Plaster of Paris, thus giving a white dot over a black stage.

Now suppose we have a scattered slide, and some part (or parts) has some object of special interest which one wishes to find quickly at some future time—all that is needed when the object is squarely on the stage is to make an ink dot on the slide exactly over the white dot on the stage. Other dots can be made if needed, and marked A, B, C, etc. Then for the future all that is necessary is to place dot A, B, or C over the white dot on the stage, and the desired part is in the centre of the field of the eye-piece.

With regard to Dr. Evans's paper, he has specially mentioned crystals, but I do not think any instrument is so efficient for examining minute crystals as the one introduced by Mr. Allan B. Dick. In this instrument you can introduce a minute crystal on the cross wire, and it does not alter its position at all.

Dr. J. W. Evans: No one appreciates more than I do its valuable qualities, but it is impossible to apply the methods devised by Professor Beck for the study of interference figures to a microscope with rotating nicols, at any rate without very considerable modification, and in the second place the small upper Bertrand lens cannot compare in convenience and effectiveness for the examination of the interference figures of minute objects with a Beck lens placed above the eye-piece, in conjunction with a diaphragm placed in the focus of the latter.

Col. J. Clibborn: We have heard to-night an immense amount of detailed information as to what is desirable, but nobody has suggested yet the means by which we may attain our object. I do not think there is any doubt that what is desirable is that we should, at all events, have one standard microscope which will fill the conditions that have been mentioned. We should at all events have one pattern—it is possible that we may require other patterns—but we at any rate require one pattern of standard microscope, because it is only possible to manufacture in very large quantities. These instruments cannot be manufactured cheaply, even in large numbers, unless you have suitable machines, and the question is how are we going to arrive at this condition of things. I do not think it can be done by separate manufacturers, because it is not possible that the patterns will all agree. The manufacturers might all join together and form a combination, and perhaps it might be done in that way, but I think the best way is what I suggested 12 months ago, namely, that a Committee should be appointed of the ablest men interested in the question, inside and outside the Society, to devote themselves to the design of the standard microscope. It should undergo as much criticism as can be brought to bear upon it, and then we should endeavour to get an instrument made and tested. If we do not, I am perfectly certain that the manufacture of the microscope will leave this country and go to the Continent.

Dr. J. R. Leeson: An important question is that of price. I have been trying for four years to fit up my little laboratory with microscopes, but I cannot get them; at least, if I can get them I cannot find the heart to pay for them. Scientists are not rich people, and if you are going to popularise the microscope, you must have an instrument that is within the reach of the ordinary individual. If you do not, then the trade will again leave this country.

Dr. R. Mullineux Walmsley: The last speaker and the last speaker but one have referred to matters with which I have been somewhat associated through the British Science Guild. A Committee has been proposed here to-night, but I would like to inform the proposer that the work he suggests has already been done. The British Science Guild first of all invited well-known users of microscopes to schedule their requirements. Having collected and collated these schedules, we asked the manufacturers to join the Committee and tell us whether it was possible from their point of view to produce microscopes which would fulfil their requirements. Eventually by the combination of the scientific men who were using the microscopes and of the manufacturers, we drew up and published specifications for three or four standard instruments for different purposes. We were in the middle of the Great War at the time, and the object was to see whether manufacturers would consider placing such instruments on the market, when peace came, with such added modifications as the progress of time might render desirable. The question of price was not overlooked, although I do not know that the prices we put down in 1917 can be held to at the present time.

The evidence of the work is on record, both in the *Journal of the British Science Guild* and the Royal Microscopical Society, and I fancy that the manufacture of both instruments exhibited to-night were to some extent influenced by the specifications prepared by the Committee.

Mr. Conrad Beck said that the standard instrument made by his firm was made to the specification of the British Science Guild Committee, but the larger one, made by Messrs. Swift, was quite a different matter. The latter was more of a special research type. He certainly welcomed the suggestion that a small sum of money should be put up to assist in manufacturing microscopes. But what was meant by a small sum? In some instances upwards of £20,000 had been spent in tools and machinery; Messrs. Watson and his own firm had each expended an enormous amount of money on machinery and tools which it was hoped in course of time would be found advantageous to microscopical work, and if a small sum meant something of this nature it was an excellent proposition.

Mr. Watson Baker: The microscope which our firm has made according to the specification of the British Science Guild is not here to-night, but I am glad to take this opportunity of saying that we should welcome any members of the Royal Microscopical Society to our works to see exactly what is being done.

I believe that Col. Clibborn himself would be pleased to see that microscopes are being made by machinery in a manner not hitherto done in this country. It has taken us 12 months to put up a new building and make the necessary tools, but we have accomplished it, and if British users could be induced to visit us and see what we have done and what it has involved, we should be very pleased.

Mr. Perkins: I was struck by the remark of Professor Desch in his paper when he said that microscopes wear because of the bad material of racks and pinions. I have found in a fairly long experience of microscope repair that sometimes the German slides are softer than the English slides, so that does not, in my opinion, account for the fact that the English microscope wears quicker than the German. It has always seemed to me that the English makers, in spite of their undoubted ability, overlook the fact that if you want to reduce wear on the slides of a microscope, they must bear properly upon each other. It is no good putting in slides which bear at points, as in Fig. 1. Wear very quickly takes place at those points and develops a shake, and you get a loss of stability, such as Professor Barnard spoke of. The closest analogy I can put forward is an ordinary bearing. If, for argument's sake, the inner bearing is much smaller than the outer (Fig. 2), you get point metal to metal contact and quick wear. If, however, it fits as in Fig. 3, the lubricant stops in in an unbroken film, and you get long and efficient wear. I have seen microscopes 20 years old which have no shake in them and still fit perfectly all over. Then, again, the weakness of design of the usual spring fitting is another point which

in my opinion English manufacturers have always overlooked. If you spring at four corners, like *a*, *b*, *c*, *d* (Fig. 4), the fitting E has got to be a very fine fit, and also the fitting F, but directly you start springing E you distort F at once. I have seen it; I have spent hours over it worrying about it, but English makers are

FIG. 1.

FIG. 2.

FIG. 3

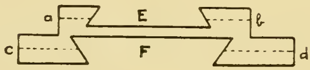


FIG. 4

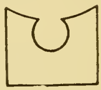


FIG. 5.

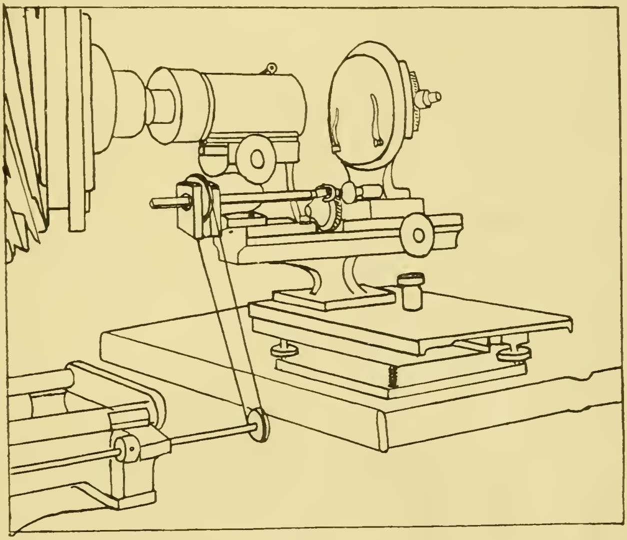
gradually waking up to the fact that you have got to have your slides in a springless chunk of metal, something like that shown in Fig. 5, so that when you do the screws up, the chunk of metal remains as it was and does not distort. Again, how can you efficiently remove the grinding material from the springing slots, which is another obvious source of wear.

Mr. Beck: Was the microscope 20 years old which you referred to German or English?

Mr. Perkins: It was German. I am not saying that I have not seen an equally good English instrument 20 years old, but I am speaking of English instruments as a body. Another point is that English makers must now see to it that they have an efficient system of inspection. The Germans have a very efficient system of inspection, and English makers must see that nothing leaves their factories which is not perfect. When you have got to that point, but not before, then success is assured.

Mr. Harold Wrighton: It fell to my lot to prepare the photomicrographs which were shown in the paper given by Sir Robert Hadfield and Mr. T. G. Elliot at the Symposium. These photographs were taken on a Zeiss-Martens horizontal machine. In order to obtain them I found it necessary to alter radically the long distance fine focussing adjustment. Even in the best patterns of photomicrographic apparatus the design and efficiency of this long distance focussing fittings seems to receive very little attention. Possibly a description of the new arrangement may be of interest to some gentlemen who have a similar Zeiss-Martens outfit.

The arrangement shown in the accompanying sketch was made in the works at very small cost, and has proved very satisfactory. The short metal rod which fitted into the socket on the focussing rod has been replaced by a longer rod, $\frac{1}{4}$ in. square in cross section. A $1\frac{1}{2}$ in. pulley wheel, turning on flanges, is mounted on a bracket at the corner of the microscope base. A square hole through the pulley wheel is just large enough to allow of very slight play between the wheel and the square rod. As the square rod will pass along through the pulley wheel, horizontal traverse of the microscope stage is not interfered with. A long rod is mounted in brackets screwed



to the base, which carries the camera. This rod has a $\frac{3}{4}$ in. pulley wheel at one end, which is connected by cord to the other wheel. At the other end is a 2 in. milled brass head, for turning. The two grooved wheels over which the cord passes are milled inside the grooves, thereby preventing slip. The arrangement as made to dimensions given above further reduces the speed of fine adjustment by one half. The main advantage is that, owing to slight play between wheel and square rod, any slight torsion produced whilst turning the rod can ease itself when the hand is removed, without turning the fine adjustment and disturbing the focus.

Another matter, referred to by a previous speaker, is the lack of contrast in most metallurgical specimens as compared with a biological section. This is one of our difficulties, and, as a matter of fact, most of our photomicrographs show considerably more contrast than is actually present in the specimen.

Mr. T. Smith: I would like to have spoken on the optical side of the discussion, but there is one matter I will refer to. We have been given some figures by Commander Ainslie based on a displacement of 1/100 mm., and some further results on a basis of the same magnitude, with the displacement along the axis, may be of interest.

I have worked out some figures relating to a 2 mm. objective. N.A. = 1.4, which gives perfect definition when used properly. With the object displaced 1/100 mm. from its proper position, I find that the marginal rays, instead of converging to the paraxial image point, get farther and farther away from the axis. This indicates how accurately it is necessary to focus at high magnifications. Therefore I would like to suggest that manufacturers of apparatus for high power work and particularly for ultra-violet microscopy should pay special attention to the problem of adjusting the specimen accurately in relation to the objective. Particularly when short wave-lengths are being used, as in ultra-violet microscopy, is this necessary if much time is not to be wasted in taking useless photographs.

The Chairman: We now proceed to the discussion of the OPTICS OF THE MICROSCOPE, and I will ask MR. WHIPPLE, President of the Optical Society, to take the Chair.

Mr. R. S. Whipple: I think that at this stage of the proceedings we ought to congratulate Messrs. Beck on the fact that they have been able to produce a standard microscope and that they have been able to keep their promise to produce it this month. As a manufacturer I know the difficulty of keeping a promise of this kind, and it is greatly to their credit that they have been able to keep to time. As a manufacturer, I also know some of the difficulties involved in the production of a new instrument. They have covered the foot of the stand with ebonite. To do this is in itself an achievement; they have introduced this ingenious geometric arrangement for holding the objectives, another considerable achievement. Thus in this apparently simple looking article there are a number of mechanical achievements—I venture to say great achievements—which a few years ago would have been regarded as impossible. I think, therefore, that it is not right to pass from the mechanical side of the microscope without expressing our indebtedness to them for what they have done so far, and to wish them and other English microscope makers every success in the future.

Abstracts of the following papers were then presented:—

THE OPTICS OF THE MICROSCOPE.

PROFESSOR A. E. CONRADY, "Microscopical Optics."
DR. H. HARTRIDGE, M.A., "An Accurate Method of Objective Testing."
MR. H. S. RYLAND, "The Manufacture and Testing of Microscope Objectives."
MR. F. TWYMAN, "Interferometric Methods."

DISCUSSION.

Mr. Conrad Beck: I have been greatly interested in the Hartridge test for microscope object glasses. Whether the graphs that you get are any value or not, it is impossible to say. I should not at present like to express the slightest opinion; all I can say is that I was interested to find that the graphs which we took in succession

one after the other with the same object glass were fairly consistent, which, considering the conditions under which these observations are made, is rather remarkable, because one is using an extremely small portion of the object glass at one time. The principle is that by the use of a small diaphragm you are illuminating a small zone of the object glass, and the numerical aperture of the portion you are illuminating is very small. I did not expect that our results would agree, because of the extremely inferior image produced with such a small portion of the object glass being used at one time. In discussing this matter with Dr. Hartridge, he pointed out that his microscope was not nearly sufficiently rigid for the purpose. The matter has been considered by my firm, and they came to the conclusion that there was no microscope sufficiently rigid for the purpose, and consequently for the last eight weeks we have been designing an instrument which I am proposing to make for my own personal use that I hope and think will be the most perfect microscope stand ever made. I shall show it to the Society as soon as it is made. Those who use the microscope for general work may consider it too elaborate and expensive for ordinary purposes, but I am not sure. It will have some features about it that will make it unusually rigid. Its construction is an interesting engineering problem, and whether anybody will ever order a similar one may be doubtful, because the cost will be very great.

There is one point made by Dr. Hartridge in his paper which I think is an obvious error, and if it were pointed out I think he would admit it. The method of testing the object glass is only a test to see whether the light from a lens is going to one point. It is not a test of the sine condition. That must be carried out as a separate test, and I am bound to say that my own impression is that when the Hartridge test is worked out and his method of calibrating and plotting out has been done, we shall find we are testing an important, but not by any means the most important, correction on an object glass. The important points about an object glass, apart from achromatic corrections, are firstly, that the light from the whole object glass shall go on to a point, and secondly, that the focal length of every zone in the glass shall be the same, and it is this latter point that the sine condition guarantees. Mr. Hartridge's test has some analogy to the Hartmann test; it measures the lateral shift of the uncorrected rays instead of the longitudinal error.

Commander M. A. Ainslie, R.N.: I should like to concentrate attention on the subject of the condenser. Professor Conrady refers to the incorrect position of the iris diaphragm; this is certainly most marked, but there are one or two points to be considered in this connection. There is no reason why the iris diaphragm should not be placed between the top lens of the condenser and the next lens, or perhaps a little lower down; at any rate, much higher up that it is at present. The diaphragm could be very well worked by means of a bevel wheel and a pinion coming out radially; the only thing against this is that the stage is so thick. It would be quite impossible on the standard instrument here shown, but if we were to return to the "horseshoe" type of stage designed by Nelson, it could be done perfectly easily. Presumably, however, the exit pupil of the objective is in the neighbourhood of its upper focal

plane; as a general rule I fancy it is rather lower down, but the position does not seem to be constant, even in objectives of the same type. If the obliquity of illumination at the margin of the field mentioned by Professor Conrady is to be avoided, the iris will have to be in the back focal plane of the condenser; if that is the case, no lateral movement of the condenser will affect the position of the image of the iris-aperture in the back lens of the objective, and it will be impossible to judge of the centering by looking down the tube.

Again, I think that both opticians and users of the microscope are content with too little in connection with the performance of the condenser; and I should say that the objection that the slide is composed of " window glass " introduces another " bogey." The area involved is always small, and if an oil immersion condenser is used, the surfaces of the slip cease to exist optically. At any rate, with a first rate modern achromatic condenser, such as the Watson " Parachromatic," it is possible, when the light source has a screen extending half way across it, to focus with such sharpness an image of the edge of this screen on the object that one row of dots on, say, *Pleurosigma Angulatum* shall be in full light and the next in " full darkness "—and this with an N.A. in use of not less than 0.7. This means that it is possible to get sharpness of the order of $\frac{1}{50,000}$ of an inch. But this is only done on one condition, and that is that the distance of the light-source is carefully adjusted to the thickness of the slip; as carefully as we adjust tube-length to the thickness of the cover glass. This point is almost universally avoided by the text-books, and I want to bring it forward as strongly as possible.

Mr. **T. Smith**: With regard to increasing the resolving power of microscope objectives, there is little doubt that the numerical aperture, as it is ordinarily understood, can hardly be increased with advantage, but there is considerable prospect of obtaining increased resolving power by using shorter wave-lengths of light. There are very considerable difficulties at present in the way, but I see no reason why they should not be overcome, although an extraordinary amount of experimental work will be involved. It is necessary to know the properties for such light of a very great variety of materials. Where we already possess some knowledge of the behaviour of certain materials with regard to ultra-violet light, this information must become much more precise than at present before it can be considered adequate, and I should like to see some definite encouragement given to researches of this character, because they can hardly fail to lead to results of value to the microscope user. Coming now to objectives and their design, it seems to me that this subject has never been investigated systematically, but that new objectives have generally been a further development of old designs on known lines. I should like to see systematic investigations undertaken, so that we may know what prospect there is of effecting real improvements in the corrections. For example, in a high power objective we have a lot of lenses placed very close together, though I am not aware of any thorough investigation which justifies adherence to this arrangement. There are obvious difficulties in the way of large separations; nevertheless, there would appear to be some decided advantages to

be gained. At present with apochromatic lenses the curvature of the field is due to the properties of the transparent materials we employ. In general they have very similar properties as regards relative dispersion, and this imposes very severe limitations on what can be achieved; but these limitations no longer hold if the lenses are well separated, and it is possible that material improvements may be effected by radical alterations in the type of objective. There would be difficulties in doing this with objectives for ordinary use, but they would hardly apply at all for a special instrument required to give very great magnification, such as the metallurgists ask for, and I think these investigations might very well be made in regard to objectives for this particular purpose. In fact, I think we want to see a very great deal more of the design and manufacture of objectives for special purposes instead of expecting one objective of a given focal length to do any and every job. It ought to be realised more generally that an objective of high resolving power differs markedly from a so-called universal objective like a photographic anastigmat. A microscope objective of large N.A. is necessarily a very poor instrument for any conditions but precisely those for which it is designed. There are many other points to which attention might be called, but it must suffice now to mention one. A great deal has been said about the variation in the definition given by similar objectives made by the same firm from similar glass, which ought therefore to be identical in performance. I want to suggest that a possible contributory cause may be insufficiently accurate centering of the surfaces. I do not think that investigations have ever been carried out on methods of getting surfaces centered to an extraordinary degree of accuracy, yet a very high degree of accuracy is obviously required in a microscope objective. I have seen photographic lenses under examination with the interferometer, and these have shown marked irregularities in the wave front towards the periphery of the lens. When we seek the highest possible resolving power, it is the periphery of the lens that is all important, so I think we want to see, among other things, an investigation into methods of getting surfaces centered, not twice as accurately as we do them at present, but perhaps 10 or even 100 times as well. If any manufacturer were able to effect such an improvement, he would probably find that his lenses would realise a much more uniform standard of excellence than those produced at the present time. I very much hope that in some of the directions I have indicated the National Physical Laboratory may be able to give assistance to our own manufacturers.

Mr. J. E. Barnard: Mr. Smith has just referred to the question of investigation by the use of radiations of short wave-length. I should have hesitated to bring the subject up again had it not been that Professor Conrady also referred to it in his paper, and by a curious chance he has dropped into a not unusual error. He says that the limitations of the work are in part laid down by the opacity of bodies to ultra-violet light. When you get down to the dimensions with which we are dealing in a microscopic object which is at or beyond the ordinary resolution limits, opacity is almost non-existent. Sir George Beilby has shown that very thin metal films

are almost perfectly transparent, and yet metals are the most opaque of substances. Latterly I have been endeavouring to photograph by means of ultra-violet light some exceedingly small organisms, some of which are beyond the limits of resolution, and the difficulty has been that with any wave-length I have at present available, the organism is transparent. The radiations pass completely through, and I am unable to get an image of any description whatever. So that to say that the limitations of the work are largely governed by the opacity of small bodies is not in accordance with practical experience or theoretical expectations. It may possibly arise if we use radiations of much shorter wave-length than those at present available, but in that case we shall be working with a microscope *in vacuo*, and I do not think it is a point which is likely to arise in practice for some time to come, although it may, and probably will, arise at a later stage.

Mr. L. C. Martin: I was interested in the description of the Hartridge test for the microscope objective, but I should like to say that it is not often, I believe, that a man testing a microscope objective wishes to know the aberration to any great accuracy, but rather whether the microscope objective is sufficiently good for the purpose. Therefore a somewhat easier quantitative test is to be desired. At the present time I have been doing a certain amount of work as a sort of preliminary study of the star test, and I think that possibly the so-called Rayleigh condition of less than one quarter wave-length a speedy test of the aberrations of a microscope objective.

Professor Conrady remarks in his paper that the fulfilment of the so-called Rayleigh condition of less than one quarter wave-length difference of optical paths between paraxial and marginal rays in good telescope and microscope objective, has been demonstrated by the Hilger interferometer. It is easy to understand that, imagining a perfectly spherical mirror in the interferometer and a means of controlling the position of such a surface to correspond with any particular focus of the test lens, such a perfect demonstration could be given. It is not easy to understand, however, when we consider that the errors of the surface of a mirror, which may be of the order of $\frac{\lambda}{4}$ or even more, are doubly important in such a case, and that the position of the test focus has to be obtained by trial. It is only when we consider a fact which was hinted at by Lord Rayleigh in 1879, and worked out by Professor Conrady in his paper on Star Discs, viz., that the effects of spherical aberration can often be countered very completely by changes of focus (or in mathematical language that we can partly balance the terms of the fourth and higher orders in the aberration expression by a change of the coefficient of the second order), that we can realise that the indications of the interferometer are trustworthy even to the extent previously indicated. It is necessary to bear in mind, however, that there is nothing magically sensitive in the interferometer tests as compared with star tests, for example, if these are performed with the maximum of care. Those who expect them to give tremendously sensitive results far excelling all other tests are doomed to disappointment.

Mr. Beck: Will you explain to us whether a quantitative measurement is obtained in the star test. The star test has been in use with the microscope objective ever since the achromatic microscope objective was known, in the form of a minute mercury globule reflecting a small source of light which makes practically an artificial star.

Mr. Martin: The work I have been doing is in a very unadvanced stage, but I hope it will be possible to obtain a rough estimate of the variation of the spherical aberration.

Commander Ainslie: I had the curiosity to test a low power objective on the well-known Wassel method, and it was easy to obtain (by this particular method of the extinction of the two sides of a zone simultaneously, with a screen), numerical values for the different foci of the different zones. I was only using a low power objective, an half-inch apochromat, and it would be difficult with high powers, unless, perhaps, an auxiliary telescope is used.

Mr. T. Smith: Mr. Beck said that the Hartridge test would not give coma. May I suggest that it is quite easy to get coma by plotting the spherical aberration for two somewhat different magnifications. From these numerical values, the deduction of the coma is quite easy.

Professor Eyre, in bringing the discussion to a close, said :

The time has now come when I must close the meeting. It is very difficult at the end of an evening o this character to sum up with anything like precision or to offer an opinion that has any value on the work that has been presented. There is, however, one outstanding feature, namely, that workers are willing and anxious to state their requirements to the manufacturers, and I think we have evidence that the manufacturers on their side are willing to do all in their power to help meet these needs. We cannot expect perfection at once. As Mr. Watson Baker has said, it has taken quite a year to get his factory and the machinery ready. It has been the same with all manufacturers and I do trust now that the necessities of the workers have been placed clearly before the manufacturers that we shall soon reach a stage when we shall have an instrument of our own manufacture, not only for home use, but one which will also enable us to capture the world's trade in microscopes.

APPENDIX I.

Catalogue of Exhibition,

Held in connection with

THE SYMPOSIUM AND GENERAL DISCUSSION

ON

The Microscope: Its Design, Construction and Applications,

On Wednesday, January 14th, 1920, in the Rooms of the Royal Society, Burlington House, Piccadilly, W.1.

GROUND FLOOR.

A Selection of Microscopes from the Collection in the Science Museum, South Kensington.

Lent by the Board of Education.

The instruments selected are arranged in chronological order, and illustrate the development of the compound microscope from the end of the sixteenth century until towards the middle of the nineteenth century.

Jansen's microscope (1590) is represented by a facsimile copy, and Hooke's microscope (1665) by a photograph of the Plate in his "Micrographia."

The rest are chiefly examples of the work of the leading English opticians of the eighteenth and early nineteenth centuries, viz., Marshall, Culpeper, Cuff, Martin, Adams, Mann, Watkins, Bleuler, Dollond, Smith, Ross, Powell, Tulley, and Pritchard.

To mark the introduction of the apochromatic objective a microscope by Zeiss, made in 1888, is also shown.

These instruments, which are not the property of the Board, are exhibited by permission of the owners, Mr. Thomas H. Court and Mr. Edward M. Nelson.

Descriptive labels are shown with the instruments.

LIBRARY.

(First Floor.)

Mr. Charles Baker.—Demonstration of photomicrographic apparatus, equipped for metallurgical research work, ultra-condenser, concentric dark ground illuminator, and recent introductions of new microscopes and objectives.

Mr. A. C. Banfield.—Thirty glass transparencies illustrating the application of the microscope to low power stereoscopy. The subjects shown range in magnification from four diameters to seventy.

Mr. J. E. Barnard and Mr. F. Welch.—Quartz and glass mercury vapour lamps as illuminants for the microscope.

Professor W. M. Bayliss, F.R.S.—

(a) Ultra-microscope of Siedentopf-Zsigmondy pattern, showing Brownian movement in colloidal gold.

(b) Heating chamber for use with " cardioid " condenser, showing cessation of Brownian movement on gelatin.

Messrs. R. and J. Beck, Ltd.—The Beck Standard London Microscope to specification of the British Science Guild. Sloan object changer. High-power dark ground illuminator. Beck micrometer eye-piece.

Messrs. Bellingham and Stanley, Ltd.—Instruments for measuring refractive indices.

Improved Abbe refractometer; all British design, enables refractive indices of solids or liquids to be determined at average accuracy of two units in the fourth place. The partial dispersion C—F can also be measured. The immersion refractometer shown is identical in principle, but is designed for use with liquids, being suitable for alcohol determinations. Refractive index plays an important part in microscopy, not only for materials used in objectives, but also in the case of various mounting media.

Messrs. Boots' Pure Drug Company, Ltd.—The use of the microscope in pharmacy and pharmaceutical chemistry.

Messrs. British Colloids, Ltd.—Colloidal suspensions under dark-ground illumination, to show Brownian movement.

Messrs. British Dyestuffs Corporation (Huddersfield), Ltd.—Dyestuffs used for staining.

Basic Colours:—

Auramine O.
Bismarck Brown R.100.
Magenta Crystals.
Malachite Green Crystals A 25 per cent.
Methyl Violet 2B.
Methylene Blue 2B.

Acid Colours:—

Nigrosine G. Crystals.
Orange G.

Messrs. The Cambridge and Paul Instrument Company, Ltd.—Reading microscope. Microscope used in the accurate cutting of screw threads. Microtomes.

Messrs. Chance Bros. and Company, Ltd. (Mr. F. E. Lamplough).—Optical glass.

Mr. A. Chaston Chapman, F.I.C.—Some cultivated and "wild" yeasts in pure culture; the former are used for brewing and distilling purposes; some of the latter are frequently a source of trouble in the brewery.

Messrs. Co-operative Wholesale Society, Ltd. (Dr. Geoffrey Martin, F.I.C.).—The use of the microscope in the preparation of foodstuffs.

Messrs. Courtaulds, Ltd.—The use of the microscope in the textile industry.

Exhibit A.—Samples of artificial silk and cloth, and microscope with sample of cloth under low power, illustrating employment for studying character of textiles.

Exhibit B.—Microscope with sample of natural souple silk stained blue, illustrating identification of fibres.

Exhibit C.—Microscope with cross-sections of modern viscose artificial silk, and photomicrographs showing differences in cross-sections of typical artificial silks, illustrating identification of origin and method of manufacture.

Messrs. F. Davidson and Company.—The "Davon" patent super-microscope and optical bench for direct visual observations under high power, large field and great "depth of focus," and embodying a new method of photomicrography.

Mr. D. Finlayson, F.L.S., and Mr. Raymond Finlayson, F.R.M.S., F.Z.S.—The microscope and its uses in seed analysis. Identification and comparison of different species of seeds and their adulterants, by means of a revolving disc attachment to stage of microscope.

The Geological Survey and Museum (Sir Aubrey Strahan, F.R.S.).—A series of photomicrographs to illustrate the mineralogical constitution and structure of rocks as revealed by the petrological microscope, and specimens to illustrate the mode of preparation of thin rock-sections for microscopical examination.

Lieut.-Col. William Gifford.—Monochromatic light filters for use in high-power microscopy and photomicrography. F line for visual work, G for photography.

Messrs. Flatters and Garnett, Ltd.—Photographs of textile fabrics and fibres.

Mr. J. W. Gordon.—Demonstration of the principles of illumination in the microscope, with special reference to:—

1. Wide-angled lighting.
2. Narrow-angled lighting.
3. Wide-angled vision.
4. Narrow-angled vision.

Messrs. Hadfields, Ltd.—Photomicrographs of iron and steel.

Mr. R. J. E. Hanson, F.R.C.S.—

Dyoptikon (Eye-piece) Headrest.

[Applicable to any existing standard microscope.]

A sliding headrest is provided, with rubber tubular buffer—to lessen fatigue and mal-orientation of the eyes and to secure effective retinal adaptation and stimulation of (R and L) visual cortex.

A Solution of Visual Purple.

Dr. H. Hartridge.—

(1) Apertometry by means of the descending light-path.

(2) Water-soluble immersion medium for use with high-power objectives.

(3) Critical illumination with immersion condenser, the light source being attached to and forming part of the microscope.

Dr. W. H. Hatfield.—Photomicrographs illustrating application of microscope to metallurgical work.

Mr. E. Hatschek.—Ultra-filters for retaining ultra-microscopic particles. Collodion membrances are used as septa: according to the method of preparation they may be used with pressure (Bechhold) or they may work with hydrostatic head only (Wo. Ostwald).

Messrs. Hawksley and Sons.—Microscopes by the Spencer Lens Company suitable for research work, students' models, also travelling model in all-metal case. Blood examination apparatus. Thoma-Hawksley haemacytometers with various rulings.

Mr. C. F. Hill and Mr. H. C. Lancaster.—The use of the microscope in the metallography of lead. Typical samples of lead, containing antimony, tin, copper, and zinc. Also a new bearing metal, made of lead, containing calcium and barium.

Miss Nina Hosali.—Models illustrating crystalline form and symmetry.

Messs. Ilford, Ltd. (Mr. F. F. Renwick).—Exhibit arranged to show the range and spectrum of thirty colour filters, including a set of nine micro-filters, eight spectrum (single-band) filters, tricolour filters and their complementaries, mercury vapour lamp filters and photographic correction filters.

Jaeger Laboratory (Mr. A. E. Garrett).—

Exhibit Illustrating the Analysis of Textiles.

The microscope is the final Court of Appeal in the testing of textile materials in so far as the nature of their constituent fibres is concerned.

There is no difficulty in dividing the more generally used fibres into the following distinct classes:—

1. Wool and other animal hairs.
2. Silk.
3. Cotton.
4. Other plant fibres (flax, ramie, jute, etc.).

Classes 1 and 4 are, however, as indicated, subject to much subdivision.

Class 1 contains wool, camel hair, alpaca, vicuna, cashmere, mohair, and a few less well-known hairs. Class 4 contains all the multi-cellular fibres obtained from the stems or leaves of plants, and their number mounts up considerably, especially if those employed for sacking, rope, etc., are included.

The distinguishing features in Class 1 are the diameter of the fibres, the colour of the pigment when present, the distribution of the pigment cells, and scale structure or other surface markings.

In Class 4 the diameter of the fibres, the nature of the cell walls—uniform thickness, etc.—the size of the lumen, and superficial markings help in the recognition of the fibre. Polarised light will often assist in this section.

The microscope can also be used to determine:—

(a) Whether the fibres are in their normal state or have undergone treatment which has altered their shape. Mercerised cotton is a good example.

(b) Whether coloured fibres owe their tint to natural pigment or dye. The pigment cells appear as separate units, while the dyed fibres appear of uniform tint throughout.

Messrs. Jeyes' Sanitary Compounds Company, Ltd. (Mr. W. C. Reynolds, F.I.C.).—Illustrating the theory of emulsions.

Messrs. Kodak, Ltd.—Filters for photomicrography, spectroscopy, tri-colour photography, filter-holders and other photomicrographical accessories, plates for photomicrography.

The Photomicrographic Society.—

Mr. F. Martin Duncan, F.R.M.S., F.R.P.S., F.Z.S.—Prints of low and high power photomicrographs, including bacteria, etc.

Dr. G. H. Rodman, F.R.P.S.—Transparencies of photomicrographs of a variety of subjects, in viewing frame.

Mr. E. A. Pinchin, F.R.M.S.—Transparencies of photomicrographs of diatoms, in viewing frame.

Mr. F. Ian G. Rawlins.—A moderate-sized "ordinary" microscope, modified for use in metallography.

Features:—

(a) Substage arrangement.

(b) Modified objectives (converted to short barrel from standard lenses).

(c) Half-watt lamp, affording sufficient illumination at minimum expense and trouble.

Mr. J. Rheinberg.—Some Applications of:—

(1) Filmless photography.

(2) Grainless photography.

(3) Platinised and semi-platinised surface mirrors.

Mr. Sydney W. Ross, F.R.M.S.—A new apparatus for the microscopic examination and photomicrography of metallic specimens (two forms, drawings only).

Research Department, Woolwich.——

(1) Microscope with filar micrometer eye-piece, used for the measurement of small Brinell ball hardness impressions (0.2 to 0.8 millimetre in diameter) to 0.001 millimetre.

(2) Photomicrographs of structures found in gun-steel, shell-steel, etc.

M. Eugene Schneider and M. Charles Florian.—A microscope for measuring Brinell depressions. (Constructed by the Société d'Optique et de Mécanique de Haute Precision, Paris.)

Sheffield University, by kind permission of the Vice-Chancellor, Sir W. H. Hadow (Professor W. Ripper, and Dr. J. O. Arnold, F.R.S.).

Original Specimens Belonging to Sorby.

(1) The following is a description of the Sorby micro-sections:—

Dr. H. C. Sorby's pioneer micro-sections of iron and steel, made in 1863-5.

Lent in 1889, for Dr. Sorby's lifetime, to Professor J. O. Arnold, F.R.S., and bequeathed on Dr. Sorby's

death in 1908 to the Metallurgical Department of the University of Sheffield.

(Prepared by Dr. H. C. Sorby, F.R.S., at "Broomfield," Sheffield, 1863-5.)

(2) The gold copper series of micro-sections prepared by Professor J. O. Arnold, F.R.S.:—

Pioneer sections made by Professor J. O. Arnold, F.R.S., and Mr. Joseph Jefferson in 1893, showing the micrographic influence of small amounts of impurities on the structure of pure gold and copper, hence the discovery of brittle intercrystalline cements.

These were fully described in *Engineering*, February 7th, 1896.

(3) Framed signed portrait of the late Dr. H. C. Sorby, F.R.S.

Professor Alexander Silverman (University of Pittsburgh).—A new illuminator for opaque objects. (Exhibited by Mr. S. C. Akehurst.)

Dr. J. E. Stead, F.R.S.—An improved form of workshop microscope designed by Dr. J. E. Stead and Messrs. J. Swift and Son.

Series of heat-tinted specimens, showing the structure of phosphoretic steels and metals.

Dr. Marie Stopes.—The microscope as applied to coal research. Illustrated by thin sections of coal, showing differences in texture and of plant content.

Mr. J. Strachan.—The use of the microscope in the examination of paper-making materials.

(1) A series of slides showing various paper-making fibres, including both those in common use and a few unusual fibres used during the war.

(2) A series of slides showing dendritic growths of copper compound in paper, illustrating the application of the microscope to the study of chemical changes taking place in paper after its manufacture.

Messrs. James Swift and Son, Ltd.—Microscopes for metallurgy and mineralogy and apochromatic objectives.

Messrs. Taylor, Taylor and Hobson, Ltd.—

A microscope for measuring the diameters of depressions made when testing the hardness of metals by the Brinell method.

The magnification is 16 diameters.

A graticule is incorporated enabling diameters up to about 7 mm. to be measured.

The microscope stands on three feet, one of them being a cloven foot, within the notch of which the object is easily centred in the field of the microscope. The other two feet are adjustable up and down by means of a knurled nut.

The focal plane of the microscope coincides at all times with that of the underside of the cloven foot, so that no focussing is necessary.

The optical system is contained in a single tube, and may be removed as a separate unit. The field and object glasses and the graticule are held in the tube by a novel and very simple means (patented) without screws.

Accuracy of the instrument is guaranteed within .01 mm.

Messrs. W. Watson and Sons, Ltd.—Microscopes, objectives and accessory apparatus.

APPENDIX II.

THE WORK OF THE FARADAY SOCIETY,

And a brief reference to Michael Faraday,

BY THE PRESIDENT OF THE FARADAY SOCIETY

(SIR ROBERT HADFIELD, Bart., D.Sc., D.Met., F.R.S.)

As in addition to our own Members, we have a large number of visitors present to-day, I thought it would be of interest to write a short account of the work of our Society, which takes its name from one of the greatest of the Scientific Immortals—Michael Faraday. I need hardly say how glad we shall be to receive an access to our Membership of those interested in the work we are trying to accomplish, which is not only that of covering certain ground not dealt with by other Scientific Societies, but also of arousing interest in the minds of the younger men in our great Metropolis and elsewhere with regard to Scientific developments.

I also take this opportunity of saying a few words about Faraday, who devoted his life to Science, with but one single aim—to advance its position in the world, and to benefit Mankind without fear or favour to rich and poor alike. No monetary or selfish considerations ever entered his mind.

At the time I accepted the invitation of the Council in 1914, conveyed through my friend, Professor A. K. Huntington, to be your President, I was not in good health, and the duties seemed to be far too great for me to undertake. I felt, however, that it was a special honour and privilege to be asked to follow in the footsteps of some of our great Masters of the Past—Kelvin, Swan, and others—so I accepted.

When delivering my Presidential Address in June, 1914, I little dreamt that our Empire was so soon to pass through a time of unexampled stress. Notwithstanding the difficulties with which those five troublous years were surrounded, I am glad to say our work never relaxed, and I do not think we suspended a single meeting, Council, Committee, or General. Thanks to the willing help given on all hands, whether by the Council, by the Members, or by our Secretary, Mr. F. S. Spiers, it has given me no little satisfaction to think that the younger men amongst us have been aided in their work by our Society and its gatherings.

My work with the Faraday Society has been a labour of love. The time is, however, coming when I am sure you must think it only right that another of your Members should take my place as President. Let me add that I have only been too glad to give any help in my power, and its future will always have the warmest interest of my heart.

Our Society owed its origin in 1902, chiefly to a little band of workers who met together to advance the great cause of Scientific Knowledge. It was founded on February 4th, 1903 at a meeting in the rooms of the now defunct Faraday Club, held at St. Ermin's Hotel, Westminster. Amongst its founders were Mr. Sherard Cowper-Coles, Mr. W. R. Cooper, Professor F. G. Donnan, Dr. F. M. Perkin, Mr. Alexander Siemens, Mr. James Swinburne, and Mr. F. S. Spiers, our present Secretary, to whom we owe a deep debt of gratitude for his indefatigable work on behalf of our Society, and to whom there should be accorded a crown of laurels. To each of these Founders I have sent a special invitation asking them to be present this evening.

Our first President was Sir Joseph Swan, F.R.S., later Lord Kelvin, followed by Sir William Perkin, F.R.S., Sir Oliver Lodge, F.R.S., Mr. J. Swinburne, F.R.S., and Sir R. T. Glazebrook, F.R.S., whose portraits are given in the accompanying plate. The objects of the Society as originally defined were to promote the study of Electro-chemistry, Electrometallurgy, Physical Chemistry, Metallography, and kindred subjects.

I venture to think that we are accomplishing the objects for which its founders set out, and that the Faraday Society will continue to increase and flourish. It is, however, very desirable that we should extend our Membership, and I trust a great effort will be made by every present Member to bring in at least another new Member, also that many of our Visitors to-night will join our Roll Call. Stagnation in any Society means final decay. If we fulfil a useful purpose, as we undoubtedly do, then the aim I have set forth of a large increase in Membership ought to be possible. In one important Technical Society in America, I learn they have this year increased their Roll Call by no less than one thousand new Members.

Our Society is honoured and recognised in the Councils of the larger and parent Societies. It has a seat on the Conjoint Board of Scientific Societies and is consulted along with other Societies on the special subjects with which we deal and are acquainted. The fact that the Royal Society has this evening granted us the privilege of holding our Symposium in its historic building also shows, I venture to think, that our work meets with the approval of this great parent body of Scientists.

Nitrogen Products Committee.—I will refer to one subject in which we gave a helping hand during the War—in fact it might be said that the Faraday Society originated this special Research in this Country, namely, that relating to Nitrogen Products, which mainly through our suggestion was taken up by the Munitions Inventions Board. My friend, Professor Huntington, of King's College, worked in season and out of season to get the Government Department concerned interested. He finally succeeded in persuading the Munitions Inventions Department to appoint a Special Nitrogen Products Committee, who in their turn were instrumental in establishing a Research Department. As Mr. H. W. Dickinson, Secretary of the M.I.D., points out, so much spade work was done by the Department with regard to this subject that

when at a later date owing to the submarine campaign the policy of the Ministry changed and it was decided to go to new sources for Nitrogen supply, the results of the research work and of the information gathered by the Research Department mentioned were ready to hand and enabled practical work on a large experimental scale to be commenced at once.

It should be added that the work was taken up for the Committee by one of our Members of Council, Dr. J. A. Harker, F.R.S., who was allowed by the National Physical Laboratory to assist in this important development, his labours being of the highest value. The Country is greatly indebted to him for the untiring devotion he has shown in working out this special and important subject to a successful issue. Our Council hope that before long they will be able to present a Report to us describing in detail the work carried out. The Report of the Committee itself is shortly to be published, and it will probably be one of the most remarkable documents in regard both to scope and matter that has been issued by a Government Department during those troublous times.

The work done, although not immediately made use of for War purposes, as the Armistice rendered any help needless in this quarter, will, without doubt, bear great fruit in the future; in fact, the Nitrogen Factory, which was being started during the War, has already been taken over by a private organisation. It is therefore probable that the Nitric Acid required in this Country for making explosives, dyes and drugs will be produced synthetically in this manner.

Symposia previously held.—Since the formation of the Faraday Society, we have had approximately 330 papers presented to us, most of them fully discussed. During my own term of office—1914 to 1919—some 180 papers have been read, and, including the present one, there have been fifteen Symposia held, attended by considerably over 3,000 Members and Visitors. The following shows these in tabular form:—

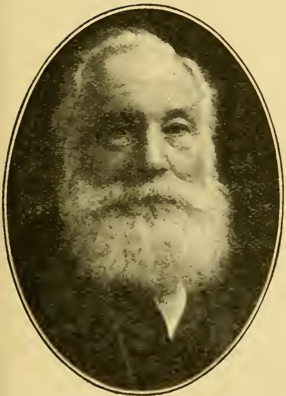
No.	Date.	Title.
1	Nov., 1914	The Hardening of Metals.
2	Oct., 1915	The Transformations of Pure Iron.
3	Dec., 1915	The Corrosion of Metals.
4	Mar., 1916	Methods and Appliances for the Attainment of High Temperatures in the Laboratory.
5	Nov., 1916	Refractory Materials.
6	Mar., 1917	The Training and Work of the Chemical Engineer.
7	May, 1917	Osmotic Pressure.
8	Nov., 1917	Pyrometers and Pyrometry.
9	Jan., 1918	The Setting of Cements and Plasters.
10	Feb., 1918	Electric Furnaces. (Symposium at Manchester.)
11	May, 1918	The Co-ordination of Scientific Publication.
12	Nov., 1918	The Occlusion of Gases by Metals.
13	Jan., 1919	The Present Position of the Theory of Ionisation.
14	April, 1919	Radiometallography.

THE FARADAY SOCIETY

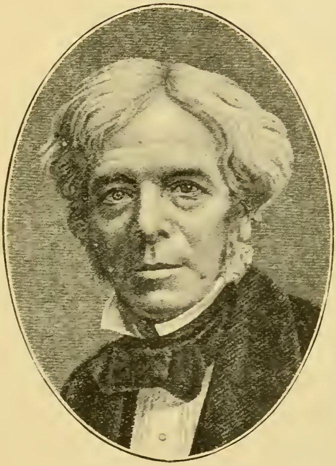
and six of its Past Presidents.

Sir JOSEPH SWAN
(First President)
1903–1904

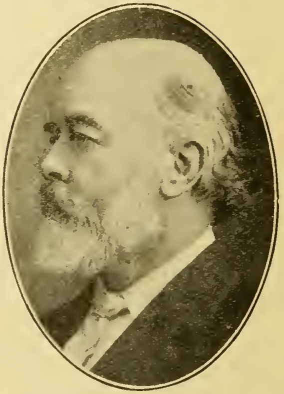
Lord KELVIN
(Second President)
1905—1907



Sir WILLIAM PERKIN
1907–1908

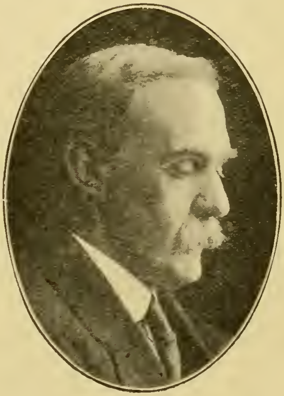


MICHAEL FARADAY
1791–1867



Sir OLIVER LODGE
1908–1909

JAMES SWINBURNE
1910–1911



Sir RICHARD GLAZEBROOK
1912—1913

It is hoped that the present Symposium will be no less successful than previous ones. Many Members and others at home and abroad have expressed their thanks for the useful work done by our Society. We have also tried to give a helping hand and encouragement to the younger men in our midst. This has been one of the chief objects we have always had specially in mind. Let our motto be "Thoroughness," and we shall continue to flourish and do still better work in the future.

The Work of Michael Faraday.—Turning now for a moment to Michael Faraday, from whom our Society takes its name, I will a little later on refer to one of the descriptions of the Great Scientist, by Professor John Tyndall, F.R.S., in his lecture before the Royal Institution in January, 1863, on "Faraday as a Discoverer."

De la Rive, the well-known French Scientist in his "Notice on Faraday's Life and Work," Archives des Sciences de la Bibliothèque Universelle, October, 1867, stated that the number of Faraday's Memoirs from 1820 to 1855, all of these important, was almost incredible.

Faraday was born at Newington Butts on the 22nd September, 1791, and finally passed away at Hampton Court on the 25th August, 1867.

Tyndall said that it seemed desirable to give the world some image of Michael Faraday as a scientific investigator and discoverer. He regarded the attempt to respond to this desire, whilst a labour of difficulty in adequately presenting a history of this great man, as also a labour of love. However well acquainted he might be with the researches and discoveries of the great master—however numerous the illustrations which occur to him of the loftiness of Faraday's character and the beauty of his life—still to grasp him and his researches as a whole; to seize upon the ideas which guided him and connect them; to gain entrance into that strong and active brain and read from it the riddle of the world—was a work not easy of performance. As he was a believer in the general truth of the doctrine of hereditary transmission, Tyndall, who shared the opinion of Carlyle that a really able man never proceeded from entirely stupid parents—said that he once used the privilege of his intimacy with Faraday to ask him whether his parents showed any signs of unusual ability. He could remember none. His father was a great sufferer during the later years of his life, and this might have masked whatever intellectual power he possessed. When thirteen years old, that is to say in 1804, Faraday was apprenticed to a book-binder in Blandford Street, Manchester Square; here he spent eight years of his life, after which he worked as a journeyman elsewhere.

Faraday was only 22 years of age when he obtained a position in the Royal Institution. His first contribution to Science appeared in the Journal of the Royal Institution in 1816, that is, in the publication known as the "Quarterly Journal of Science." I thought it might be of interest to give the following summaries by Tyndall of (1) Researches by Faraday, and (2) Discoveries by Faraday :—

RESEARCHES BY FARADAY.

	PUBLISHED
First contribution to Science—Analysis of Caustic Lime from Tuscany ...	1816
Experiments on Sounding Flames ...	1818
Vaporisation of Mercury at Ordinary Temperatures ...	1821
On the Limits of Vaporisation ...	
Experiments on Alloys of Steel ...	
Vibrating Surfaces ...	1829
On the Quantitative Comparison of different forms of Electricity	1833
On the Absolute Quantity of Electricity associated with the particles or Atoms of Matter ...	
The Power of Metals and other Solids to induce the combination of gaseous Bodies ...	
Extra Current—The influence by induction of an Electric Current upon itself ...	1835
On Frictional Electricity, Induction, Conduction, Specific Conductive Capacity, and Theory of Contiguous Particles	1835 to 1838
Further Researches on Liquefaction of Gases—Establishing the fact that Gases are vapours of Liquids possessing very low boiling points ...	1844
Speculations on the Nature of Matter and Lines of Force ...	1846
On the Diamagnetic Condition of Flame and Gases ...	1847
On Magne-Crystallic Action and Lines of Force ...	1848 to 1851
Magnetism of Gases ...	1850
Atmospheric Magnetism ...	
Electricity of Gymnotus ...	
Source of Power of the Hydro-Electric Machine ...	
Regelation ...	

DISCOVERIES BY FARADAY.

	PUBLISHED
Two new Compounds—Chlorine, Carbon and Iodine; Carbon and Hydrogen ...	1820
Alloys of Steel ...	1821
Magnetic Rotations ...	
Liquefaction of Gases ...	1823
Change of colour of Glass in Sunlight ...	1825
New Compounds of Hydrogen and Carbon ...	1826
Benzol ...	
Improvements in manufacture of Glass for Optical purposes. Afterwards the foundation of most important Discoveries, *e.g.*, Magnetisation of Light ...	1829
Peculiar class of optical deceptions—optical toy, the Chromotrope owed its origin to this ...	
Magneto-Electric Induction—Tyndall says: "Greatest experimental result ever obtained by an investigator. The 'Mont Blanc' of Faraday's achievements"...	
Terrestrial Magneto-Electric Induction ...	
Identities of Electricities—Static, Voltaic, Magneto, Thermo, etc.	1833
New Law of Electric Induction ...	
Laws of Electro-Chemical Decomposition—Definite Electro-Chemical Decomposition. Tyndall says: "This Law ranks in importance with that of the Definite Combining Proportions in Chemistry" ...	
Origin of Power in the Voltaic Pile ...	1834
Magnetisation of Light and the Illumination of the Lines of Magnetic Force. In other words, the Rotation of the Plane of Polarisation ...	1845
Diamagnetism or the Magnetic Condition of all Matter ...	
Atmospheric Magnetism ...	1850

SUMMARY OF FARADAY'S WORK.

I will also quote Tyndall's Summary of Faraday's work somewhat fully as it is indeed worth reading. It is a stimulus to each of us according to his light to go and try to do likewise, even if in a smaller and humbler way.

Tyndall says:

"When from an Alpine height the eye of the climber ranges over the mountains, he finds that for the most part they resolve themselves into direct groups, each consisting of a dominant mass surrounded by peaks of lesser elevation. The power which lifted the mightier eminences, in nearly all cases, lifted others to an almost equal height. And so it is with the discoveries of Faraday. As a general rule, the dominant result does not stand alone, but forms the culminating point of a vast and varied mass of enquiry.

In this way, round about his great discovery of Magneto-Electric Induction, other weighty labours grouped themselves. His investigations on the Extra Current; on the Polar and other conditions of Diamagnetic Bodies; on Lines of Magnetic Force, their definite character and distribution; on the employment of the Induced Magneto-Electric Current as a measure and test of Magnetic Action; on the Repulsive Phenomena of the Magnetic Field, are all, notwithstanding the diversity of title, researches in the domain of Magneto-Electric Induction.

Faraday's second group of Researches and Discoveries embraced the chemical phenomena of the current. The dominant result here is the great Law of Definite Electro-Chemical Decomposition, around which are massed various Researches on Electro-Chemical Conduction, and on Electrolysis both with the Machine and with the Pile. To this group also belong his Analysis of the Contact Theory; his Inquiries as to the Source of Voltaic Electricity, and his final development of the Chemical Theory of the Voltaic Pile.

His third great discovery is the Magnetisation of Light, which may be likened to the Weisshorn among mountains—high, beautiful, and alone.

The dominant result of his fourth group of Researches is the discovery of Diamagnetism, announced in his Memoir as the Magnetic Condition of all Matter, round which are grouped his enquiries on the Magnetism of Flame and Gases; on Magne-Crystallic Action, and on Atmospheric Magnetism, in its relation to the annual and diurnal variation of the needle, the full significance of which is still to be shown.

These are Faraday's most massive discoveries, and upon them his fame must mainly rest. But even without them, sufficient would remain to secure for him a high and lasting scientific reputation. We should still have his Researches on the Liquefaction of Gases; on Frictional Electricity; on the Electricity of the Gymnotus; on the Source of Power in the Hydro-Electric Machine; on the Electro-

Magnetic Rotations; on Regelation; all his more purely Chemical Researches, including his discovery of Benzol. Besides these he published a multitude of minor papers, most of which in the same way illustrate his genius."

Tyndall adds that no allusion is here made to his power as a Lecturer. Taking him all in all, it will be conceded that Michael Faraday was probably the greatest experimental Philosopher the world has ever seen. The progress of future research will tend not to dim or diminish, but to enhance and glorify the labours of this mighty investigator.

Speaking with regard to my own lines of research. as representing the Faculty of Metallurgy, I may mention that Faraday, in his experiments on Alloys of Iron with other Elements, in other words the production of Alloy Steel, carried out in 1821 and 1822, showed that a remarkable inspiration evidently existed in his mind as to the great future this line of research work presented. Singular to say it is just about 100 years ago that Faraday wrote several letters from the Royal Institution (in April and June, 1820), to his Swiss friend De la Rive, Professor of Chemistry, Geneva, in which he gave an account of some experiments on Steel made by himself and Stodart. The world's great technical advances during the last thirty years have been—and I say it unhesitatingly—in a large measure due to the introduction of Alloy Steels such as Faraday had in mind. As already mentioned, Faraday, with Stodart, started these researches at the Royal Institution, finally completing the experiments by sending his various mixtures to be melted at the Sanderson Works in Sheffield, this Firm being still in existence to-day. The specimens had to be sent by coach, the work being given to a trusty assistant who had to go down and see the experiments put in hand and completed. Beyond the work of Mushet this particular land of Research lay fallow for many years, in fact it was my own discovery and invention of Manganese Steel in 1882 which showed that the new world already indicated by Faraday was there ready to be explored. This exploration has rapidly taken place during the last thirty years, including the discovery and invention of Chromium Steel, Silicon Steel, Nickel Steel, Tungsten Steel, High-speed Tool Steel, Non-corroding, and many other types of Steels.

Almost as important was the fact that Alloy Steel necessitated special heat treatment, which again required and called for the use of scientific methods for the determination of temperatures, critical points, microstructure study, improved analytical methods, mechanical testing, hardness determination, observation of electrical conductivity, magnetic susceptibility, electrical resistance, hysteresis effects and other qualities.

In conclusion, this Society is indeed honoured in being allowed to bear the name of so great a man as Faraday, whose work is still benefiting our Empire.